IMPLICATIONS OF THE REVISED NIOSH LIFTING GUIDE OF 1991: A FIELD STUDY

By

Nina Lynn Brokaw
B.S. Michigan State University, 1979

A Thesis
Submitted to the Faculty of the
Graduate School of the University of Louisville
in Partial Fulfillment of the Requirements
for the Degree of

Master of Science

Department of Industrial Engineering
University of Louisville
Louisville, Kentucky

December 1992

IMPLICATIONS OF THE REVISED NIOSH LIFTING GUIDE OF 1991:
A FIELD STUDY

By

Nina Lynn Brokaw
B.S. Michigan State University, 1979

A Thesis Approved on

12/7/92
(DATE)

by the following Reading Committee:

Dr. Waldemar Karwowski, Thesis Director

Dr. Thomas L. Ward

Dr. R. K. Ragade

Dr. J. W. Yates

ABSTRACT

In 1981, the National Institute of Occupational Safety and Health (NIOSH) published the Work Practices Guide for Manual Lifting, with the goal of reducing injury from manual lifting in the workplace. The 1981 Guide established the 1981 Lifting Equation to give industry an empirical means of evaluating the risk to a worker associated with manual lifting tasks. In 1991, NIOSH revised the guide and updated the lifting equation to reflect the latest findings in the area of manual lifting. The 1991 Lifting Equation has several significant differences from the 1981 Lifting Equation. Among these are the ability to evaluate non-symmetrical lifting tasks and consideration of the hand-to-container coupling. This field study analyzed 31 manual lifting tasks from three industrial sites in order to assess the impact the 1991 Lifting Equation may have on industry. The data from this study indicates that the 1991 Lifting Equation produces a more conservative estimate of the maximum capacity of a worker for manual lifting. Ten of the 31 lifts were asymmetrical, allowing the 1991 Lifting Equation to evaluate 47.6 percent more lifts than could the 1981 Lifting Equation.

ACKNOWLEDGEMENTS

I would like to say a special thank you to Dr Waldemar Karwowski, my Thesis Director, and Dr William Biles, the MSIE Program Advisor, for their help and inspiration these past nineteen months. They, along with the other members of the Industrial Engineering Department, have made my tour of duty at the University of Louisville a rewarding period of great personal and intellectual growth. Thanks also to Nai Pongpatanausegsa and Laura Abell for their help in preparing this document, and to the members of the reading committee, Dr. Thomas L. Ward, Dr. R. K. Ragate, and Dr. J. W. Yates.

The help of the representatives from industry who gave freely of their time and energy for this field study was invaluable. I extend thanks to Mike Gonsalves, Kevin Connell, Mary Lynn Cotton, Frank Gradisek, and Gene Holtzman for making this work possible.

My appreciation also goes to the United States Army for extending the opportunity to attend graduate school on a full time basis.

Finally, thanks to my husband, Jeff Hill, for his patience and support over the last nineteen months when being a student had to take precedence over being a wife and mother.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

General

Manual lifting has long been recognized as a major contributor to the injury of workers in industry. The costs, in terms of lost time at work and expense to indu:.try, are very large. In 1974 the National Health Council estimated that over $1 billion was spent on worker's compensation claims and medical payments as a result of low back pain cases (NIOSH, 1981). The National Safety Council statistics on the number of material-handling related work injuries, and the cost of those injuries from 1972 to 1984, show that while the incidence of injury has decreased slightly, the costs related to the injuries have increased dramatically from around 12 billion dollars a year in 1972 to over 30 billion dollars a year in the early 1980's. In 1979, it was estimated that in the United States approximately 170 million working days per year are lost because of low back pain (Ayoub and Mital, 1989).

A majority of manual material handling injuries are due to lifting. Statistics from 1979 show that 48 percent of worker's compensation claims for low back strains and sprains were due to injuries resulting from lifting objects (Loesser, 1979). A study of insurance claims from occupational accidents for an accident insurance association in Sweden in 1982 showed that of 235 accepted claims involving acute back disorders, 181 cases (almost 78%) involved lifting, carrying, and supporting loads. The remainder were due to pushing or pulling loads or operation of machinery (Metzler, 1985).

Many efforts have been made to reduce the risk of injury due to lifting. Automation of the work place, improved recognition of hazardous lifting conditions, and better methods for selection of workers are increasingly more prevalent.

In 1981, the National Institute of Occupational Safety and Health (NIOSH) published the Work Practices Guide for Manual Lifting as a comprehensive summary of information on manual lifting. This guide consisted of a summary of research available on lifting, providing the most up to date and comprehensive information available at the time. The guide also sought to provide recommendations to allow industry to control the hazards associated with some manual lifting tasks. The guide provided information on the selection of workers for manual materials handling, and recommendations on design of the workplace to lessen the risks associated with manual lifting of materials.

As a part of the 1981 Guide, an equation to evaluate the risk associated with a lifting task was developed. The lifting equation was based on available research in the epidemiological, biomechanical, physiological and psychophysical measurement of lifting. Using this model, a safety and health professional could make an empirical assessment of the potential risk of injury to a worker due to a lifting task, by measuring the physical characteristics of a lift. These physical characteristics include, among other factors, vertical location of the load, lifting distance, and lifting frequency. Through the use of this model, NIOSH hoped to reduce the incidence of lifting-related low back pain among workers in the United States.

However, application of the model was limited. For example, the model applied only to two handed lifts performed in the sagittal plane (symmetric lifting). Since this model was developed and the Work Practices Guide published in 1981, knowledge about manual lifting capacity has continued to increase. In 1985, NIOSH convened a committee of experts to update the lifting equation to reflect the results of the latest research in the area of manual materials handling. As a result of the committee's work, the model of the lifting equation was revised. In the 1991 equation, NIOSH incorporated the latest findings in the area of manual lifting, changing some of the capacity limits used to establish the 1981 equation. The new equation also provided a means to evaluate non-sagittal lifting. Other major changes to the model included the addition of a factor for less than optimal hand-to-container couplings and an expanded range of work durations and lifting frequencies.

NIOSH's 1991 objective in revising the lifting equation was to update the equation to reflect the latest findings in the area of lifting capacity of the worker. They also sought to provide a means of evaluating asymmetrical lifts, lifts of objects with less than optimal hand-to-container couplings, guidelines for a longer range of work durations and a greater variety of lifting task frequencies. In designing the new lifting equation, NIOSH predicted that, while it would decrease what was considered a safe load in some cases, the new equation would raise it in other cases. NIOSH felt that the model provided a means to evaluate some of the lifting tasks found in industry, and had the potential to reduce other musculoskeletal injuries, such as shoulder and arm disorders, in addition to reducing incidence of low-back pain associated with lifting (Waters, et al., 1993).

2. Objectives.

The primary objective of this research was to compare the recommended weight limits for jobs found in industry evaluated under the 1981 NIOSH lifting equation and under the Draft 1991 Guide. Based on this comparison, an assessment can be made about the potential impact that the 1991 lifting equation may have on industry. Injury data associated with each lifting job, when compared the results of task evaluation, may be indicative to what extent the recommended lifting limits correlate with the injuries occurring in the workplace. In addition, an objective of this research was to assess the potential utility and the ease of using both the 1981 and 1991 lifting equations as a tool for occupational safety personnel to enhance the safety of workers in the workplace.

CHAPTER II

BACKGROUND

1. The Challenge of Establishing Lifting Standards.

There are four basic approaches to the measurement of the impact of lifting tasks on the human body: epidemiological, biomechanical, psychophysical, and physiological. Each of these four approaches seeks to measure the impact of lifting on the worker in order to establish conditions for acceptable lifting. There are numerous challenges in developing a predictive model for lifting capacity using the results of research from these four approaches to the evaluation of human lifting capacity.

One of the major challenges in developing a model for the prediction of lifting capacity of a worker is the disagreement between the outcomes of these approaches to lifting (Garg and Ayoub, 1980; Ayoub, et al., 1980; NIOSH, 1981). Utilizing only one approach to the measurement of lifting capacity may lead to much higher or lower values of safe lifting limits than that other approaches.

Another difficulty is in the multitude of variables which impact the maximum permissable and acceptable load a worker can safely lift (Garg and Ayoub, 1980). Among these are the variables concerning worker, load lifted, lifting task, and working conditions. Worker variables include the gender, age, physical conditioning, history of previous injury, body weight, height and strength (NIOSH, 1981; Ayoub, et al., 1980). Load variables can include the object size, shape, stability, design, and distribution of the weight within the load (NIOSH, 1981; Ayoub, et al., 1980). Lifting task variables include frequency of lift, height of lift, distance moved, and accuracy with which the load must be placed (NIOSH, 1981; Ayoub, et al., 1980). Working conditions, such as noise, vibration, lighting, heat and humidity can also impact the acceptability of a lifting task (NIOSH, 1981).

With the numerous variables and the differences in scientific approaches to measuring the acceptability of a lifting task, research results are often difficult to correlate. Recommended weight limits based on the different approaches to manual lifting vary widely. Wide variations also exist in recommendations for maximum permissible weight of the load exist for studies based on the same criteria (Garg and Ayoub, 1980). In the 1981 Work Practices Guide, NIOSH attempted to integrate the recommendations from the four approaches to set acceptable lifting limits into one set of recommendations.

2. Basic Approaches to Establishing Lifting Criteria.

a. The Epidemiological Approach.

An epidemiological approach to a health problem is one which concentrates on the incidence, distribution, and potential controls of illness and injuries on a population. In an epidemiological approach to studying the effect of lifting on the human body, researchers look for identifiable factors which increase the risk of injury to a worker, and attempt to establish statistical relationships between these factors and the risk of injury to the worker. These factors can be divided into job risk factors and personal risk factors (NIOSH, 1981). Job risk factors include the size and weight of the load, and frequency of the lift. Personal risk factors include the gender, age, strength, lifting technique, attitude and training of the worker.

(1) Limitations of the epidemiological approach.

One limitation in the use of the epidemiological approach to the study of lifting is that the researcher is usually dependent on accident and injury reports provided by industry. In many cases, the reported accident information has limitations. While there are legal requirements to report some accidents, many companies also keep information on non-reportable accidents and injuries. Typically, the systems used by industry to collect most of the accident and injury data are not designed with the aim of gathering information for the prevention of accidents. There is little uniformity in the approach used to gather injury information in various companies, making it difficult to compare accident rates between industries with any degree of confidence (Nicholson, 1985). For many researchers, it was "epidemiologically expedient" to lump together all reported episodes of back pain attributable to work irrespective of diagnosis or cause (NIOSH, 1981). Often, an epidemiological approach can provide information for the evaluation of injury trends in an industry and comparison of trends between injuries.

Another limitation on the use of the epidemiological approach to lifting is the nature of back pain (NIOSH 1981). Back pain can result from primary or secondary causes. Primary back pain results when the tissues of the back are in a state of neurological, *mechanical, or biochemical irritation* because of fatigue, postural stress, injury, or local pathological change due to degeneration. Secondary back pain is caused by a lesion which affects the nerve supply to the tissues of the back. For example, a mechanical derangement of the spine can cause the stretching or angulation of a nerve root from its normal path. This type of injury may cause pain, weakness, or numbness in the lower limb in the area of distribution of the nerve root. Back pain is seldom localized and cannot be measured. The severity of pain experienced has no direct relationship to the cause of the pain. It is difficult to accurately identify the site and origin of back pain, since the pain can radiate. The pain experienced and the sites from which pain arise may not be closely related. The disk and joint-facets of the spine can be injured, but lack a nerve supply, so the injury may go unnoticed until secondary effects occur.

(2) Job risk factors.

NIOSH (1981) identified several lifting job risk factors commonly reported in literature as potentially hazardous to the musculoskeletal system. These factors were:

1) weight of the load lifted,
2) position of the load center of gravity with respect to the worker,
3) frequency, pace and duration of the lifting task (repetitiveness),
4) stability of the load (consistency of the center of gravity),
5) texture, handle size and location, and other couplings with the load,
6) spatial aspects of the task in terms of movement distance, direction, postural constraints, obstacles, etc.,
7) environmental factors such as temperature, humidity, illumination, noise, vibration, frictional stability of the foot, etc.

Of these seven areas, only the first three had been sufficiently researched to form any basis for guidance on the development of a lifting capacity model.

(a) Weight of load lifted.

The weight of the load lifted had the most obvious correlation to the potential injuries. The NIOSH (1981) literature review reported that more back injuries occurred in "heavy" industries than in "light" industries, with jobs commonly being classified as heavy, medium, or light work. Studies conducted in the mid- to late-1970's, cited by NIOSH (1981), concluded that there was a relationship between the weight lifted and injuries from lifting. These researchers found that the heavier the load lifted, the greater the incidence and severity of injury. A 1978 study (Ayoub, et al., 1978) established job severity indices which were based on job variables such as the size and weight of the load and the frequency of the lift. The job severity index was the ratio of job demand to the capacity of the worker for a given set of working conditions (Ayoub and Mital, 1988). As the job severity indices increased, so did the severity of musculoskeletal disorders.

(b) Load center of gravity.

In these studies, the physical dimensions of the load were found to be a contributor to the incidence of back injury. In a 1977 study, Chaffin found that the frequency and severity of musculoskeletal injury increased the further away the center of gravity of the load was from the body. This applied for loads which were held away from the body due to bulk of the load or workplace layout (NIOSH, 1981).

(c) Frequency of lifting.

Like weight of the load and distance of the load from the body, frequency, duration, and pace of lifting were found to have a relationship to injury potential in lifting tasks. Higher frequency lifting was found to be related to increased injury incidence rates.

(3) Personal risk factors.

Epidemiological studies indicate that personal risk factors, like job factors, play a role in the risk of injury due to lifting, but the role is less clearly defined. NIOSH found that capacity for lifting varied greatly from one individual to another, and varied within an individual over time. The personal risk factors were found to be complex and interrelated.

(a) *Gender.*

Gender, NIOSH (1981) concluded, plays a role, but that role was secondary to strength. Numerous studies cited by NIOSH lead to the general consensus that the strength of females is about sixty percent that of males. The average female will be more severely stressed than the average male when lifting a given load. However, since the ranges of strength for males and females are large, the issue for acceptability of a given lift lies more with strength than with gender of the worker.

(b) Age.

According to NIOSH (1981), the greatest incidence of low-back pain occurred in the 30 to 50 year old group. This was in contrast to the expectation that higher incidence of injury would occur in older workers. It was not known if this was due to older workers being less exposed to the hazards of lifting, or if those prone to back injury had already been eliminated form lifting tasks, leaving only the healthiest of older workers in the higher age groups. Ayoub and Mital (1989) suggest that the higher incidence of low back injury in younger workers is due to a combined effect of screening older workers from the most hazardous jobs and overloading the bodies of the younger workers.

The NIOSH guide suggests that younger workers may not have developed the capability to recognize a hazardous lift. These workers may be stressing the body during a lifting task, but have the strength to avoid injury. An older worker, who is more prone to injury may compensate with better lifting techniques. Literature does indicate that heavy work done when the worker is young can lead to accelerated rates of injury as the worker ages (Blow and Jackson, 1971; Brown, 1971). NIOSH (1981) concluded that while age should be considered a potential risk factor, the details of the relationship between age and incidence of injury were not yet fully understood.

(c) Anthropometry.

NIOSH (1981) found that no clear relationships exist between anthropometry and risk of injury from lifting. Body weight was found to have an effect on metabolic energy expenditure during lifting. A heavier worker expended more energy while lifting and carrying loads, leading to earlier fatigue. However, a heavier person is often stronger than a lighter person, and may be able to better counterbalance large loads.

(d) Lifting technique.

Much controversy has existed over the proper lifting technique, but NIOSH (1981) found that no controlled epidemiological study had validated any of the theories on the proper lifting posture. One theory is that loads should be lifted with an erect back, starting in a squat position with the load between the knees, close to the torso. This posture reduces the compression forces on the spine and better distributes the stresses on the vertebrae. Detractors of this theory point out that this mechanical view of lifting ignores dynamic loading of the back and knees when executing the lift, and the more practical fact that many loads are too large to fit between the knees. One study suggests that the best method is to allow the worker to use common sense in determining the lifting posture rather than to try to teach the worker to assume predetermined postures to conduct a lift (Anderson, 1970). Studies showed that the squat lift was found to rarely be used in lifting heavy loads, and the NIOSH guide did not try to suggest a single proper lifting technique to be used. The issue of posture effects on lifting is further reviewed in the biomechanical approach to lifting.

(e) Worker attitudes.

Worker attitudes, values and job satisfaction could not be linked to an assessment of risk in the NIOSH review of the epidemiological approach to lifting. The literature did support an important role for training and work experience in the reduction of lifting hazard, but a clear epidemiological association could not be established. NIOSH (1981) found that there is epidemiological support for strength testing as a means to match a worker to a lifting job. This relationship is examined further under the psychophysical approach to evaluating lifting.

(4) The epidemiological approach to manual lifting.

The 1981 Work Practices Guide (NIOSH, 1981), concluded that due to the problems with measuring and interpreting low back pain, longitudinal studies provide the most reliable estimate of lifting hazard and risk. NIOSH concluded that heavy load lifting contributes to increased frequency and severity rates for low back pain, regardless of the repetitive or dynamic nature of the lifting. Repetitive lifting, however, creates medical hazards beyond low back problems, particularly for weaker workers. It was also acknowledged that personal risk factors such as gender, age, and anthropometry modify the risks of injury for populations of workers, but that the variability of these factors preclude using them to assign risk to any particular individual.

b. The Biomechanical Approach

Biomechanical lifting models are based on the analysis of internal and external forces on the body to determine the compression on the spine. These models estimate the stresses imposed on the spine during a lift by estimating the reactive forces and torques on the various joints. Biomechanical models do not directly predict lifting capacity of an individual. They can be used to determine the compression and shear forces on the low back and other joints during manual material handling tasks. Most studies of lifting tasks concentrate on the forces generated at the L4/L5 and L5/S1 discs in the lumbar region of the lower back. It is at these disks that the greatest moments are generated during lifting. Statistics on back disorders show that between 85 and 95 percent of all disk herniations occur at these two discs. The herniations are equally divided between the two sites (Chaffin and Anderson, 1991).

(1) Biomechanical models.

Most models at the time of the 1981 Work Practices Guide were restricted to sagittal lifting, although recent models incorporate three dimensional lifting, allowing for the evaluation of non-sagittal lifts. Biomechanical models best provide information on infrequent, non-repetitive lifting tasks (Garg and Ayoub, 1980) where strength is more of a factor than endurancc or energy demands.

Biomechanical models can be static or dynamic. A static model assumes that the lifting task is performed slowly and that the forces due to moment acceleration can be neglected. The reactive forces and torques are computed for various joints at discrete static positions in the lifting posture. The torques are then compared to the voluntary torques of a subject to establish the maximum lifting strength of that subject. A dynamic model considers the subject's movements and the forces generated due to those movements. Dynamic models also consider the relative forces and torques at the various body joints and the compression and shear forces at the L4/L5 and L5/S1 discs. Dynamic models can estimate the force-time relationships as the subject conducts a lift (Ayoub, et al., 1980). Dynamic lifting results in higher forces acting on the body than static lifting.

(2) Effect of stresses on the back during lifting.

The weight lifted and the person's method for lifting the weight both contribute to the stresses induced on the spine during lifting. The problem is not in the heavy load which lifting tasks impose on the muscles, but on the wear and tear imposed on the intervertebral disks (Grandjean, 1988). The muscles may be capable of handling the high forces a lift produces, but the connecting tissues, cartilage and bones may not.

Axial loading compression tests on cadaver spinal columns have been used to determine the amount of compression that can be tolerated by the spinal column. Two separate cadaver studies (Evans and Lissner, 1959; Sonoda, 1962) were cited by NIOSH (1981). These studies showed that there were large biological variations in the disc's ability to withstand the stresses imposed. The force required to cause disk failure decreased with the age of the subject. The older the subject, the lower the force required to cause a failure. It was found that failures were due to failure of the cartilage end-plates that fail, rather than the disks themselves, if the disks were healthy.

The large variation in the strength of the cadaver spinal columns (the ability of the columns to withstand the forces applied) may be due to the weakening of the cartilage end-plates through previous stresses. NIOSH (1981) postulated that the capability of the disks to withstand compression loads would decrease due to this weakening of the end-plates, causing pressure on adjacent nerve roots. This causes symptoms which are slow to develop, starting with dull aching pain, progressing to incapacitating discomfort hours or days later. When low-back pain is sudden, the incident is easily remembered and reported and can be correlated to a specific lift. Most low-back pain, however is not of the sudden variety, resulting in poor statistics relating injury to the physical act which caused the injury. This provides a biomechanical explanation for one difficulty in examining lifting from an epidemiological approach.

(3) Lifting posture.

Reviewing lifting posture from a biomechanical posture, NIOSH (1981) found that, from the standpoint of a biomechanical approach to lifting, the most important rule in lifting would be to ensure the torso is brought as close as possible to the center of gravity of the load before the load is lifted. The further away from the body the load is held, the larger the forces on the spine. This supports a squat position when lifting a load. However, this type of lift requires greater leg strength, causing many people to lean forward to compensate for lack of leg strength when lifting from the classic squat stance, creating additional stresses on the low back. NIOSH concluded that because of the variety in postures, the best approach is to avoid instruction on lifting posture (NIOSH, 1981).

(4) The biomechanical approach to manual lifting.

Based on the biomechanical approach to lifting, NIOSH (1981) concluded that the greater the horizontal distance of a load's center of gravity from the body, the higher the compressive forces on the low-back. It was also proposed that workers should be instructed to lift loads smoothly and symmetrically. The biomechanical criteria supported that compressive force on the L5/S1 above 650 kilograms was hazardous to most workers, while an upper limit of 350 kilograms force could be tolerated by most of the work force.

c. The Psychophysical Approach.

The psychophysical approach to evaluating lifting tasks seeks to determine limits to an individual's lifting capacity based on the worker's perception of acceptable load. In the psychophysical approach, a person adjusts the load so that repetitive lifting of the load does not result in overexertion or excessive fatigue (Ayoub and Mital, 1988). A psychophysical approach to lifting is concerned with strength and endurance of a worker. Strength is defined as the maximum voluntary force a person will exert in a single attempt. Endurance is the force a person is willing to exert repeatedly for an extended time without feeling undue fatigue. The psychophysical approach deals with a person's willingness to accept pain or discomfort during an exertion (NIOSH, 1981).

(1) Strength measurement.

Early efforts to establish psychophysical estimates of strength capacity were hampered by conflicting data from varying methods of strength measurement. In 1972, an ad hoc committee met to establish a standard for strength testing. As a result, a standardized method for the static measurement of strength was adopted in 1975. This improved the utility of strength measurements as a predictor of lifting capacity.

Static strength is defined as "the maximal force muscles can exert isometrically in a single voluntary effort" (NIOSH, 1981). Tests of static strength were found to be simple, safe to administer, and to be repeatable with a high degree of reliability for tests of a given muscle group. Correlations between differing muscle groups were found to be weak. Additionally, correlations to anthropometric characteristics such as gender and age were found have a large amount of variability. NIOSH (1981) concluded that it was inadvisable to use anthropometric variables to predict the risk to a particular individual.

For isometric exertion, a useful procedure is to measure the amount of the time to fatigue at various percentages of maximum voluntary contraction (MVC) of the muscles. At higher percentages of MVC, fatigue occurs more quickly. Heart rate and blood pressure are also used to monitor the effect of isometric exertion. Dynamic strength models were not widespread in literature at the time when the 1981 Guide was under development, although researchers had measured dynamic strength using psychophysical methods. In these experiments, the subject was allowed to select the weight of the load lifted, while all other variables were controlled.

(2) The psychophysical approach to manual lifting.

Psychophysical studies have been found to provide recommendations for the maximum permissible weight of the load for both infrequent lifting and for repetitive lifting tasks (Garg and Ayoub, 1980). NIOSH (1981) combined data from several studies to develop a psychophysical design criteria to predict lifting capacity of the 75th percentile female and 25th percentile male. The values were adjusted for frequency and to show a linear effect.

Psychophysical data was found to conflict with physiological data available. NIOSH (1981) concluded that for low frequency lifting, strength rather than endurance was the limiting factor in establishing capabilities. Limits suggested by the psychophysical approach were used primarily in establishing the limits for high frequency lifting tasks with durations of less than one hour.

d. The Physiological Approach.

The physiological approach to lifting is most applicable to repetitive lifting tasks (Garg and Ayoub, 1980). This approach uses measurement of oxygen consumption, metabolic energy expenditure, and heart rate to determine the maximum work intensity that a worker can maintain without excessive physical fatigue.

(1) Dynamic work measurement.

Physiological measurement of dynamic work most often involves measurement of oxygen expenditure in the form of oxygen uptake. Measurement of aerobic capacity, or VO_2 max, provides the upper limit of aerobic capacity for an individual. At VO_2, a person is working anaerobically. VO_2 max can be sustained only one or two minutes. VO_2 max has been found to decrease with age, and to be significantly lower in women than in men. Studies of repetitive lifting showed that VO_2 levels increased nearly linearly with an increased rate of lifting a given weight, and with an increased weight of load lifted at a sustained rate. Lifting from lower to higher heights resulted in higher VO_2 levels than did lowering a load from higher to lower heights (NIOSH, 1981). Oxygen uptake is used to estimate energy expenditure, measured in kcal.

(2) The physiological approach to manual lifting.

The physiological criteria established for acceptable lifting in the 1981 Guide divided the period of work (duration) into two levels. For lifting tasks of less than one hour duration, defined as occasional lifting, the upper limits for metabolic energy expenditure rates were defined as 9 kcal/min for physically fit males and 6.5 kcal/min for physically fit females. For continuous lifting, eight hour duration, the limits were 5.0 kcal and 3.5 kcal for males and females, respectively.

3. Development of the 1981 Lifting Equation

In the 1981 Work Practices Guide, NIOSH defined a lifting task as "the act of manually grasping and raising an object of definable size without mechanical aids." The model developed to evaluate the acceptability of a lifting task was limited to tasks which did not require extra energy consumption due to holding, carrying, pushing, or pulling. Other limitations included that the lifting activity was a smooth, two handed symmetric lift in the sagittal plane. The load lifted was restricted to 75 cm or less in width. Lifting posture was to be unrestricted, with good couplings (hand-to-object, shoes-to-floor surfaces.) Work conditions were restricted to "favorable ambient environments."

a. NIOSH Lifting Task Variables.

From the literature on the epidemiological, biomechanical, physiological, and psychophysical approaches to lifting, NIOSH (1981) defined six primary lifting task variables. These were: 1) the weight of the object lifted, 2) the horizontal location of the hands at the origin of the lift, measured from the midpoint between the ankles, 3) the vertical location of the hands at the origin of the lift, measured from the floor, 4) the average number of lifts per minute (lifting frequency), 5) the duration or period of the lifting task.

NIOSH (1981) considered evidence from each of the four approaches to lifting in development of the model for the evaluation of a lift. Figure 1 shows how each of the four factors emphasizes NIOSH's task variables.

	Epidemiology	Biomechanics	Physiology	Psychophysical
Object Weight	X	X	X	X
Horizontal Location	X	X	X	X
Vertical Location	X	X	X	X
Travel Distance			X	X
Frequency of Lift	X		X	X
Duration or period			X	

Figure 1. Emphasis of task variables by approach to lifting analysis.
(after NIOSH 1981)

b. Action Limit and Maximum Permissible Load.

The conflicting results from each of the four approaches lead NIOSH to develop an multiplicative model to evaluate a lifting task. The model assumes the independence of all risk factors. Input to the model was primarily established using the limits established by the biomechanical, physiological, and psychophysical approaches to lifting. The lifting model was designed to provide protection to the population as a whole, and was not applicable to a set anthropometric category. NIOSH (1981) recognized that there was wide variability in the risk of injury and in the performance capability of the population. Some lifting tasks, however, would be unsuitable for anyone to attempt. To allow for the wide variation in the population, NIOSH (1981) developed two limits. These limits are the Action Limit (AL) and the Maximum Permissable Limit (MPL).

The AL and MPL divide the range of manual lifting tasks into three categories. Below the AL, lifts are generally considered safe for 99 percent of male and 75 percent of female workers. Between the AL and the MPL, lifting tasks will require administrative and engineering controls. Above the MPL, lifting tasks are considered to place a worker at great risk of injury and are considered unsuitable.

Lifting above the MPL was found to cause significantly higher incidence of injury rates in epidemiological studies. Biomechanical compression forces for lifts above the MPL would generally be above the biomechanically defined limit of 650 kg at the lumbosacral joint (L5/S1). Metabolic rates above the MPL would exceed 5.0 kcal/minute for most individuals. The MPL defined a limit above which about 25 percent of the male population and one percent of the female population would be capable of lifting. Thus, lifts which were found to exceed the MPL were to be viewed as unacceptable and would require job redesign.

Lifts below the AL were believed to represent nominal risks to the majority of the population, within the capability of 75 percent of women and 99 percent of men. Compression forces at the L_5/S_1 disc at the AL were below 350 kg, acceptable to most healthy, young workers. Between the AL and the MPL, lifts were considered to be acceptable only with engineering and administrative controls, such as worker selection and training and job redesign. In epidemiological studies, lifting above the AL, but below the MPL, was found to cause moderate increases in musculoskeletal injury incidence rates.

c. The 1981 Lifting Equation.

To achieve the goal of providing a single model for the evaluation of the risk to an injury, NIOSH (1981) developed the following model to determine the AL and MPL values in kilograms:

$$AL = 40\,(15/H)\,(1-.004|V-75|)\,(0.7+7.5/D)\,(1-F/Fmax)$$

$$MPL = 3 * AL$$

where:

H = horizontal location forward of the midpoint between the ankles at the origin of the lift in centimeters,

V = vertical location at the origin of the lift in centimeters,

D = vertical travel distance between origin and destination of the lift in centimeters,

F = average frequency of the lift in lifts/minute

Fmax = maximum frequency which could be sustained under given lifting conditions (determined from a table).

This model takes the form of a multiplicative model in which factors are applied to determine the limits to acceptable lifting:

$$AL = 40 * HF * VF * DF * FF$$

where:

HF = horizontal factor (15/H),

VF = vertical factor (1-.004|V-75),

DF = (.7+7.5/D), and

FF = (1-F/Fmax).

Each of the four factors, HF, VF, DF and FF can take on a value between zero and one, and each is applied to a base weight. These factors are applied to a base weight, or load constant, of 40 kilograms. The load constant represents the maximum acceptable weight the majority of the population can lift without risk of injury, under ideal conditions. Under these ideal conditions, the value of each factor applied to the load constant would equal one, so the AL would equal 40 kilograms. The situation occurs at a standard lifting location. The standard lifting location serves as a three-dimensional reference point for evaluating the parameters defining the worker's lifting posture. In the 1981 Guide, this was defined as a load positioned at a vertical height of 75 cm from the floor and a horizontal distance of 15 cm from the midpoint of the ankles.

If any of the lifting factors equals zero, the lift will not be acceptable under any conditions, as the AL will equal zero. The range of values each factor can take on is limited in the equation, with some factors able to take on lower values, creating the potential to have greater influence on the outcome of the analysis.

(1) Horizontal distance.

The measurement of the horizontal distance is limited to between 15 and 80 cm. Fifteen centimeters was considered in the 1981 Guide to be the closest to the body an object could be carried without interference from the body. Since the evidence from the four approaches to lifting showed that the closer the object is to the body, the less risk involved with the lift, lifts held 15 cm from the midpoint between the ankles result in a horizontal factor (HF) of 1.00. While the guide defines the horizontal distance with respect to the origin of the lift, it does make provisions for using the horizontal distance at the destination of the lift. The analyst is cautioned against underestimating the AL for a lift by using a destination, rather than origin horizontal distance. The maximum horizontal distance is set as 80 cm, as object beyond this distance are out of reach of most people. Lifts with horizontal distances greater than 80 cm result in a HF of zero.

(2) Vertical distance.

The vertical distance is assumed to be between zero (at floor level) and 175 cm, the range of vertical reach for most people. A vertical distance of 75 cm results in a VF equal to one. Lifts with vertical distances above and below this height will reduce the vertical factor. The vertical factor can have values between 0.60 and 1.00, unless the lift is out of range (VF equal to zero.)

(3) Vertical travel distance.

The vertical travel distance of the load, D, is assumed to be between 25 and 200 centimeters. If the travel distance is less than 25 cm, the DF equals one. The maximum value for D is 200 (when vertical distance equals zero), making the minimum value of DF equal to 0.74.

(4) Frequency and duration.

Frequency, F, is assumed to be between 0.2 and a value of Fmax, representing the maximum number of lifts an individual could do. Fmax is determined from a table (Figure 2) as a function of the duration of lifting and the average vertical location of the load. The average vertical location of the load defines the worker's posture as stooped or upright for the lifting task. Duration of a lift was one of two categories: occasional and continuous. Occasional lifting was defined as a duration of less than one hour. Continuous lifting is defined as 8 hours duration. If the frequency of a lift is less than 0.2 lifts/minute (one lift every five minutes), then FF equals one. If the frequency of lifting is greater than F max, then the lift is unacceptable (FF = 0).

Duration	$V > 75$ cm Standing	$V \leq 75$ cm Stooped
1 hr	18	15
8 hrs	15	12

Figure 2. Fmax Values for the 1981 Lifting Equation (after NIOSH, 1981)

4. Development of the 1991 Lifting Guide.

The revision of the lifting equation consisted of several significant changes from the 1981 equation. The basic format for the equation remained the same, with a load constant potentially reduced by the multiplication of factors representing the task variables. The value of the load constant changed, as did the values of the multipliers. Two new multipliers were added to account for lifting task symmetry and hand-to-container coupling (Waters, et. al., 1993).

a. Changes From the 1981 Lifting Equation.

The standard lifting location in the 1991 equation remained at a vertical distance of 75 cm, as data supported this position as a standard. The horizontal distance increased from 15 to 25 cm. This reflected findings that showed that 25 centimeters was the minimum horizontal distance which did not interfere with the front of the body (Waters, et. al., 1993).

The load constant was reduced from 40 to 23 kilograms, based on biomechanical and psychophysical criteria. With the change in the horizontal factor from 15 to 25 cm, the revised load constant equates to a realized reduction of only one kilogram. This represents a weight which would be acceptable to 75 percent of the female population and 99 percent of the male population under ideal conditions. Due to the multiplicative nature of the lifting equation, the developers of the 1991 equation estimate that in practice the recommended weight limits produce by the revised equation are likely to be acceptable to 90 percent of the female population (Waters, et. al., 1993).

Discipline	Design Criterion	Cut-off Value
Biomechanical	Max disc compression force	3.4 kN
Physiological	Max energy expenditure	2.2 - 4.7 kcal/min
Psychophysical	Max acceptable weight	Acceptable to 75% of females and 99 % of males

Figure 3. Criteria used to develop the lifting equations (after Waters, et. al., 1993)

The new lifting equation was based on criteria established from the biomechanical, physiological, and psychophysical approaches the lifting. Because of the differences in load recommendations for the different criteria, the 1991 committee designed the lifting equation to provide a load limit less than or equal to the most conservative of the load limits for any one of the criteria. In developing the 1991 equation, when faced with conflicting data, the committee selected the most conservative approach (Waters, et. al., 1993). The upper limits established by the committee for each of the lifting criteria are shown in Figure 3.

b. The 1991 Lifting Equation.

The interpretation of outcome from the 1991 equation is different than for the 1981 equation. The new equation does away with the tiered acceptability levels of the 1981 equation. Rather than producing an AL and MPL, the 1991 equation produces one limit, the Recommended Weight Limit (RWL). This limit in kilograms is computed by the following equation:

$$RWL = 23\ (25/H)\ (1-.003|V-75|)\ (0.82+4.5/D)(1-.0032A)\ (FF)(CF)$$

where:

H = horizontal location forward of the midpoint between the ankles at the origin or destination of the lift, measured in centimeters,

V = vertical location of the hands from the floor, measured in centimeters at the origin and destination of the lift,

D = vertical travel distance between origin and destination of the lift, measured in centimeters,

A = angle of asymmetry at the origin and destination of the lift, measured in degrees,

FF = average frequency of the lift in lifts/minute, based on a duration of ≤1, ≤2, or ≤8 hours. This value is extracted from a table (see Appendix IV).

CF = assessment of hand-to-container coupling, based on load characteristics and vertical height of load, extracted from a table (see Appendix IV).

The RWL is determined by assessing an RWL for the origin of the lift and an RWL for the destination of the lift. The RWL for the lift is the lesser of these two figures. A lifting index (LI) is then computed by dividing weight of the load lifted by the final RWL for the lift, creating a ratio of load lifted to recommended weight. The LI values greater than one constitute unacceptable lifting conditions.

c. Limitations of the 1991 Lifting Equation.

Like the 1981 equation, the 1991 equation has its limitations. The new equation applies only to two-handed lifting tasks conducted in unconstrained work space. It assumes adequate working conditions, and that manual handling activities other than lifting are minimal. While the 1991 equation provides a means to consider hand-to-container couplings, adequate worker/floor couplings are assumed. One limitation of the 1991 equation is that it assumes that lifting and lowering tasks have equal risk of low back injury.

TABLE 1

LIFTING EQUATIONS OF THE 1981 AND 1991 GUIDES
(Putz-Anderson and Waters, 1991)

Lifting Factors	1981 Guide	1991 Guide
Load constant	40 kg	23 kg
Horizontal (HF)	15/H	25/H
Vertical (VF)	$1-.004\lvert V-75\rvert$	$1-.003\lvert V-75\rvert$
Distance (DF)	0.7 + 7.5/D	0.82 + 4.5/D
Frequency (FF)	1-F/Fmax	from table
Asymmetry (AF)	not available	1-.0032A
Coupling (CF)	not available	from table

H = Horizontal location of the hands from midpoint between the ankles, measured at the origin and destination of the lift.
V = Vertical location of the hands from the floor, measured at the origin and destination of the lift.
D = Vertical travel distance between the origin and destination of the lift.
A = Angle of asymmetry (angular displacement of the load from the sagittal plane), measured at the origin and destination of the lift.
F = Average frequency rate of lifting measured in lifts per minute. Duration is defined to be $\leq$1 hour or $\leq$8 hours for the 1981 Guide, $\leq$1 hour, $\leq$2 hours or $\leq$8 hours for the 1991 Guide, assuming appropriate recovery allowances.

5. Comparison of the Lifting Equations

A comparison of the lifting factors for the 1981 and 1991 lifting equations is given in Table 1. The approach taken in the 1991 Guide appears to be more conservative than the approach adopted in the 1981 guide. In the development of the 1991 equation, the authors selected the most conservative approach whenever two approaches were in conflict (Waters, et al., 1993). Additionally, by considering the lift at both the origin and destination (when control was required at the destination), then taking the most conservative of these as the recommended weight limit for the lift, the evaluation resulted in limits which were generally more conservative than the limits would be for any one of the four approaches to lifting. In contrast, in the 1981 Guide, the equation was less conservative. In the 1981 equation, the provision for using the horizontal destination of the lift exists, but is not encouraged as it may result in "making a job seem more difficult than it actually is" (NIOSH, 1981).

CHAPTER III

METHODS AND PROCEDURES

1. General Method.

This study was conducted in two stages. In the first stage, a total of 31 manual lifting tasks from 15 different jobs performed at three industrial sites were selected and analyzed using the 1981 and 1991 lifting equations. These tasks were selected to represent most of the possible lifting conditions considered under the Draft Revisions to the NIOSH Guide (1991). After the lifts were analyzed, in the second stage, injury data pertaining to the lifts was collected and analyzed.

2. Description of Selected Companies and Jobs.

Data for this study was collected a three industrial sites in Indiana and Kentucky. In order to accomplish the objectives of the study, 31 different lifting tasks were selected from these three different companies. These lifting tasks occurred in the course of conduct of 15 different jobs. The jobs and lifting tasks selected were representative of the variety of lifting tasks found in industry. No attempt was made to look at all the lifting tasks in any one industrial site, but rather to select a variety of jobs and tasks, which were representative of the range of lifts which could be evaluated using the 1981 and 1991 lifting equations.

a. Lifting Task Selection.

The three industrial sites selected represent a range of company size and type of product. All three industrial sites used in this study were plant operations affiliated with major companies. For the purposes of this study, the three industrial sites were labeled

TABLE 2

DESCRIPTION OF LIFTING TASKS

N	Company Number	Job Number	Description of Lifting Task	Lifting Plane	Weight of Load (kg)
1	1	1	Lifting a reel of paper (d=40 cm, w=6.4 cm) for placement on a spindle.	Sagittal	8.0
2	1	1	Lifting a rectangular box (l=68.5 cm, w=12.7 cm, h=40.6 cm) from an overhead holder for placement in another overhead holder.	Non-sagittal	6.8
3	1	1	Lifting a reel of paper (d=56.5 cm, w=2.5 cm) for placement on a spindle.	Non-sagittal	4.7
4	1	2	Lifting a reel of paper (d=35.6 cm, w=12.1 cm) for placement on a spindle.	Sagittal	12.5
5	1	2	Lifting a rectangular box (l=40.6 cm, w=30.5 cm, h=25.4 cm) for placement in holder.	Sagittal	19.6
6	1	3	Lifting a rectangular tray (l=67.3 cm, w=9.5 cm, h=41.9 cm) for placement on a rack (holder).	Sagittal	7.3
7	1	3	Lifting a rectangular tray (l=67.3 cm, w=9.5 cm, h=41.9 cm) for placement on a rack (holder).	Non-sagittal	3.1
8	1	4	Lifting a rectangular tray (l=65.6 cm, w=12.7 cm, h=40.6 cm) from a rack to an overhead holder.	Sagittal	10.2
9	1	4	Lifting a rectangular tray (l=65.6 cm, w=12.7 cm, h=40.6 cm) from an overhead holder to a rack.	Non-sagittal	6.8
10	1	5	Lifting a rectangular load (l=43.2 cm, w=27.9 cm, h=4.8 cm) from a conveyor for placement in a box.	Non-sagittal	1.1
11	1	5	Lifting a rectangular box (l=44.5 cm, w=29.2 cm, h=55.2 cm) from a holder for placement on a conveyor.	Non-sagittal	15.4

TABLE 2 (continued)

N	Company Number	Job Number	Description of Lifting Task	Lifting Plane	Weight of Load (kg)
12	1	6	Lifting a rectangular box (l=38.1 cm, w=32.4 cm, h=24.2 cm) from one pallet to another.	Sagittal	19.1
13	1	7	Lifting a rectangular box (l=63.5 cm, w=27.9 cm, h=27.9 cm) from one pallet to another.	Sagittal	11.2
14	1	8	Lifting a round, wooden board (d=119.4 cm) from a crate onto a stack of boards.	Sagittal	10.7
15	1	8	Lifting a rectangular wooden plank (l=190.5 cm, w=1.3 cm, h-121.9 cm) from a crate onto a stack of boards.	Sagittal	17.7
16	2	9	Lifting a rectangular box (l=58.4 cm, w=31.8 cm, h=15.2 cm) from a conveyor to a pallet located on a pallet lifter.	Sagittal	6.4
17	2	10	Lifting a rectangular box (l=95.3 cm, w=16.5 cm, h=31.8 cm) from a conveyor to a pallet.	Sagittal	15.4
18	2	10	Lifting a rectangular box (l=58.4 cm, w=31.8 cm, h=15.2 cm) from a conveyor to a pallet.	Sagittal	6.4
19	2	11	Lifting a rectangular box (l=93.3 cm, w=55.9 cm, h=4.4 cm) from a table to a pallet.	Sagittal	9.1
20	2	11	Lifting a rectangular metal part (l=91.4 cm, w=0.32 cm, h=53.3 cm) from a holder to a table.	Sagittal	8.2

TABLE 2 (continued)

N	Company Number	Job Number	Description of Lifting Task	Lifting Plane	Weight of Load (kg)
			(l=142.2 cm, w=14.6 cm, h=1.9 cm) from leaning against a pillar onto a pallet.		
22	3	12	Lifting a piece of packing material (152.4 cm x 152.4 cm) from one pile to another.	Non-sagittal	2.4
23	3	12	Lifting a piece of cardboard packing material (137.2 cm x 137.2 cm) from a vertical storage location to a horizontal location.	Sagittal	2.0
24	3	12	Lifting a reel of shrinkwrap (d=9.5 cm, l=50.2 cm) from a storage pallet and placing it on a spindle.	Sagittal	17.6
25	3	13	Lifting a rectangular board (l=111.8 cm, w=10.16 cm, h=7.6 cm) from a storage pallet onto a table.	Sagittal	8.5
26	3	13	Lifting a rectangular board (l=111.8 cm, w=12.2 cm, h=2.5 cm) from a storage pallet onto a table.	Sagittal	5.3
27	3	13	Lifting a rectangular board (l=76.2 cm, w=12.6 cm, h=2.5 cm) from a storage pallet onto a table.	Sagittal	2.0
28	3	13	Lifting a pallet (l=111.7 cm, w=111.7 cm, h=11.4 cm) from a table to a stack on a forklift.	Sagittal	25.4
29	3	14	Lifting a bag (l=50.8 cm, w=30.5 cm, h=10.2 cm) from a pallet (exact placement at destination not required.)	Non-sagittal	11.3
30	3	14	Lifting a metal bar (l-81.3 cm, w=20.3 cm, h=10.2 cm) from a pallet (exact placement not required.)	Non-sagittal	22.7
31	3	15	Lifting bricks (l=22.9 cm, w=10.2 cm, h=6.4 cm) from a pile on the floor exact placement not required.)	Non-sagittal	3.5

Company #1, Company #2, and Company #3. A total of fifteen jobs from these companies were reviewed. The jobs are numbered sequentially in this study. Each job entailed one or more lifting tasks, for a total of 31 lifting tasks. These lifting tasks are identified by a sequence number, N. Table 2 provides the lifting task sequence number, job and company for each lift. In this table, each lifting task is described. The dimensions, weight, and type of load are given. A description of each of the fifteen jobs is given in Appendix V.

b. Company Descriptions.

Company #1 was a food service manufacturing plant located in central Kentucky. This company employs approximately 3000 workers at the plant site used in this study. The jobs and lifting tasks evaluated in this study were found in three departments of this company, where product production, supply and shipping occur. These three departments contain approximately 1600 of the 3000 plant employees. Company #1 has the most formalized ergonomics program of the three companies in this study, with weekly meetings of management and worker representatives forming an ergonomics committee. At these meetings, problem areas are reviewed and solutions sought for ergonomic and safety problems. This company has placed strong emphasis on proper lifting techniques and training of workers. Fifteen lifting tasks found in eight jobs in this company were evaluated in this study.

Company #2 was an assembly plant located in central Indiana. This plant employs approximately 500 people at the plant site used in this study. Product size ranges from a product that can be assembled and lifted by one individual to large items which must be handled with special material handling devices. The smaller products are assembled and flow through the plant along conveyor systems. Active efforts to solve problems involving lifting are evident in the use of pallet lifters and other aides to lifting. Five lifting tasks from three jobs in this company were evaluated in this study.

Company #3 is a metals processing plant located in Eastern Kentucky. This plant employs approximately 1000 people at the plant site used in this study. This plant would be classified as a converter, transforming raw materials into large roles of metal stock. Since the product this plant produces is large, much of the material handling is done with cranes and massive conveyor systems. This company makes lifting a regular part of its employee safety training. Eleven lifting tasks from four jobs in this company were evaluated for this study.

3. Demographic Information.

Two female and 13 male workers were observed in the course of this research. Data was collected in the normal course of their work. Basic demographic information on these workers is presented in Table 3. Means and standard deviation for height, weight and age are given for male and female workers are given in Table 4.

4. Measurement of the Lifting Tasks.

In order to analyze a lifting task under both the 1981 and 1991 NIOSH equations, the following information is needed:

1) Horizontal distance of load from the midpoint of the worker's ankles at the origin and destination of the lift.

2) Vertical distance from the floor to the center of mass of the load at the origin and destination of the lift.

TABLE 3
DEMOGRAPHIC INFORMATION ABOUT THE WORKERS

Company	Job	Age	Height (in)	Weight (lbs)	Gender
1	1	55	62	105	F
1	2	60	73	159	M
1	3	41	72	250	M
1	4	57	70	180	M
1	5	45	69	185	M
1	6	35	70	170	M
1	7	52	67	140	M
1	8	38	72	195	M
2	9	51	60	160	F
2	10	41	72	170	M
2	11	38	63	135	M
3	12	46	67	225	M
3	13	49	76	250	M
3	14	41	69	155	M
3	15	34	70	230	M

TABLE 4
DESCRIPTIVE STATISTICS

	Mean	Std Dev	Range	
Male (N=13)			Min Value	Max Value
Age	44.38	7.83	34	60
Height (in)	70	3.11	63	76
Weight	188	37.86	135	250
Female (N=2)				
Age	53	2	51	55
Height (in)	61	1	60	62
Height (in)	132.5	27.5	105	160

3) Vertical travel distance of the load from the origin to the destination of the lift.

4) Average frequency of the lifting task in lifts per minute.

5) Duration of the lifting period in hours.

6) Dimensions, description, and weight of the load being lifted.

7) Assessment of the hand-to-container coupling.

8) Angle of asymmetry (displacement of the load from a sagittal plane) at the origin and destination of the lift.

a. Measurement Procedures.

For each of the selected jobs, the worker was observed in the course of conducting the job. Measurements were taken of the work site to provide information on the origin and destination position of the load, height of tables or machines, and other static measurements. Each load was weighed and the dimensions of the load were measured. The lifts were then video taped to allow analysis of the lifting task without disturbing the worker. From the video tape, measurements not taken at the work site were extrapolated, using the known measurements as a basis for the additional information. This allowed information, such as the distance the load was held from the body, to be collected without disturbing the worker during the normal course of the lifting task. The video of the lift was examined to confirm coupling factor and asymmetry factors. All measurements were made in U. S. Standard units and were converted to S. I. units for this study.

b. Subjective Decisions.

Certain of the lift evaluations require decisions on the measurements to use. For example, the 1981 Lifting Equation has categories for two durations of the lifting activity: 1 hour and 8 hours. The 1991 equation has three duration categories: ≤1 hour, ≤2 hours, and ≤8 hours. For the majority of the tasks evaluated in this study, the lifts fit easily into one of these duration categories. However, for three of the tasks (N = 13, 14, and 15) the duration of the lifting activity was three to four hours. In these cases, a decision had to be made as to which category to use. Similarly, in the 1981 guide, the horizontal distance used is that at the origin of the lift, unless the worker must exert control over the load at the destination of the lift. In this case, the horizontal measurement at the destination of the lift can be used. The decision is left to the person evaluating the lift, based on the control involved in he lifting task. (The guide cautions against prejudicing the outcome of the evaluation by using too conservative of a measure, as may happen when using the destination rather than the origin horizontal measure.) In the 1991 guide, a similar decision must be made by the task evaluator regarding the duration of the lifting task. The evaluator must also evaluate the hand-to-container coupling, although guidelines are given for this decision.

An attempt was made to evaluate all lifts in the same manner as would the industrial health and safety professional making decisions about the lift. In this respect, the criteria used to make the decision was to make the decision that a "reasonable and prudent" person would make under the circumstances. Some of these decisions made in the evaluation of the lifts are detailed in Appendix III. Each lift was analyzed for the necessary input data for both equations before any computations were made under either lifting equation. This precluded the results of one lifting equation from influencing the analyst in computation of the other lifting equation.

5. Collection of Injury and Work Hour Data

Injury and work hour data are contained in Appendix I. Injury data was collected by reviewing company injury logs for type and cause of injury. Only those injuries which resulted from lifting were recorded for this research. Injury data was collected from January, 1990, through August, 1992, for Companies #1 and #3. Injury data was collected from January, 1988, through August, 1992, for Company #2.

a. Injury Data.

Because of the emphasis on low back pain in the NIOSH guides, collection of injury data concentrated on back pain. Tables 14 through 17 (see Appendix I) provide a complete listing of the lifting related injuries for each company. These injuries are coded as either reportable or not reportable to the Occupational Safety and Health Administration (OSHA). For each injury which occurred as a result of one of the jobs reviewed in this study, the number of that job is given. Injuries could not be traced to a specific lifting task within a job with any amount of accuracy, so comparisons of injury rates are to all the lifts within a given job, rather than to a given lifting task.

The injury data was classified by the job and year in Tables 18 through 20 (see Appendix I) for each company. Tables 21 through 23 (see Appendix I) reflect the injuries classified by part of the body affected by the injury. The body parts are defined as back, shoulder/neck, arm/elbow, wrist (includes carpal tunnel syndrome), legs, and torso (includes chest, sides, abdomen, buttock and groin areas). In cases where injury occurred to more than one body part, the following criteria was applied to determine under which body part the injury was listed: back was given precedence over any other body part involved, shoulder was given precedence over any body part except back, and arm was given precedence over any body part except shoulder and back.

Back injuries were further subdivided by the part of the back affected. Back injuries which were described as generalized or for which a part of the back was not specified were listed together. This data is contained in Tables 24 through 26 (see Appendix I).

b. Work Hour Data.

Work hour data was collected from company records. Data was not available on the exact man-hours per job. Annual hours per job was estimated using the expert opinion of the representatives from each company, for companies #1 and #3. This quantity was based on the number of workers per shift, hours per shift, shifts per day, and days per week that the job is done. The estimated hours for Company #1 are computed as a percentage of the department workhours in which the job occurs. Company #2 work hours per year per job were provided as constant values. No accidents resulting from lifting were found in Company #2, resulting in incidence of injury rates equal to zero for all lifts in this company. Since no injuries were associated with the jobs reviewed in this study, the hours per job calculations were not made for this company. Injury data was reviewed for five years for Company #2.

c. Injury Rates.

Incidence of injury rates for years in which the entire year was calculated (all years other than 1992), were computed using the standard Bureau of Labor Statistics formula:

$$IR = (N/E) * 200{,}000$$

where:

IR = Incidence of Injury

N = number of manual lifting related injuries

E = man-hours of employee exposure

The 200,000 is based on 100 full-time employees working 40 hours per week, 50 weeks per year. For 1992, in which only the January through August time period was used, the 200,000 was reduced to 133,333.3, representing 8/12 of the hours worked in a full year. This data is displayed in Tables 27 through 30 (see Appendix I).

CHAPTER IV

RESULTS AND DISCUSSION

1. Lifting Tasks Analyzed

Thirty-one lifts from 15 jobs were analyzed in this study. Table 5 provides the raw measurement data for each lift. Horizontal lines separate the lifts by the job in which they occurred. Included in this table are the horizontal and vertical destination and origin measurements, vertical travel distance of the load, posture of the worker at the origin and destination of the lift, frequency of the lift in lifts per minute, duration of the lifting task, asymmetry of the lift at the origin and destination, coupling factor and weight of load lifted. From this information, the lifting tasks were analyzed under the 1981 and 1991 Lifting Guides.

The 31 lifts analyzed in this study represent a cross section of lifts found in industry. The three companies from which the lifts were taken vary in size and mission. Examination of the lifts by various categories provides a picture of the lifts used in this study. The manual lifting tasks are profiled in the following categories: weight of load lifted, symmetry of the lift profile, duration and frequency of lifting, and type of load lifted.

a. Load Weights.

Weights of the loads lifted in all three companies ranged from 1.1 kg to 25.4 kg, with a mean of 9.78 kg (standard deviation 6.52). Figure 4 shows the weights of the loads divided into six five-kilogram incremental categories.

b. Symmetry of Lift.

Ten of the lifts (32.2%) were asymmetrical (Figure 5). Of these, four were asymmetrical at the origin of the lift only, three were asymmetrical at the destination of the

TABLE 5

LIFTING TASK CHARACTERISTICS

N	Company Number	Job Number	Horizontal Origin	Horizontal Dest	Vertical Origin	Vertical Dest	Vertical Distance	Posture Origin	Posture Dest	Frequency* (lifts/min)	Duration (hours)	Asymmetry Origin	Asymmetry Dest	Coupling	Weight (kg)
1	1	1	25.4	38.1 +	121.9	172.7	50.8	u	u	<.2 (.05)	≤8	0	0	Fair	8.0
2	1	1	30.5	50.8 +	139.7	139.7	0.0	u	u	0.2	≤8	0	30	Good	6.8
3	1	1	43.2	43.2	35.6	43.2	7.6	s	s	<.2 (.07)	≤8	45	0	Fair	4.7
4	1	2	33.0	48.3 +	132.1	167.6	35.6	u	u	<.2 (.05)	≤8	0	0	Fair	12.2
5	1	2	43.2	38.1	109.2	94.0	15.2	u	s	<.2 (.03)	≤8	0	0	Fair	19.6
6	1	3	33.5	41.9 +	96.5	144.8	48.3	u	u	3.3	≤8	0	0	Fair	7.3
7	1	3	73.3	33.5	66.0	66.0	0.0	s	s	3.3	≤8	45	45	Poor	3.1
8	1	4	38.1	53.3 +	141.0	170.2	29.2	u	u	5.0	≤8	0	0	Fair	10.2
9	1	4	45.7	45.7	170.2	91.4	78.7	u	u	5.0	≤8	45	30	Fair	6.8
10	1	5	41.9	48.3 +	96.5	124.5	27.9	u	u	6.0	≤8	0	90	Fair	1.1
11	1	5	43.2	43.2	114.3	81.3	33.0	s	s	0.5	≤8	0	15	Fair	15.4
12	1	6	31.8	80.0 +	78.6	19.1	68.6	u	s	6.0	≤1	0	0	Fair	19.1
13	1	7	30.5	76.2 +	90.2	53.3	36.8	u	s	6.0	≤2	0	0	Fair	11.2
14	1	8	20.3	63.5	101.6	152.4	50.8	u	u	1.0	≤2	0	0	Poor	10.7
15	1	8	20.3	76.2	121.9	165.1	43.2	u	u	2.0	≤2	0	0	Poor	17.7
16	2	9	30.9	29.2	74.9	80.0	5.1	u	u	0.9	≤8	0	0	Fair	6.4
17	2	10	30.9	54.4 +	78.7	94.6	15.9	u	u	1.0	≤8	0	0	Fair	15.4
18	2	10	30.9	53.3 +	78.7	25.4	53.3	u	s	1.0	≤8	0	0	Fair	6.4
19	2	11	42.9	63.5 +	87.6	24.1	63.5	u	s	0.5	≤8	0	0	Fair	9.1
20	2	11	16.0	40.4 +	88.9	110.5	21.6	u	u	0.5	≤8	0	0	Poor	8.2
21	3	12	30.2	40.4	116.8	139.7	22.9	u	u	<.2 (.01)	≤1	0	0	Fair	2.9
22	3	12	63.5	79.1 +	76.2	114.3	38.1	u	u	<.2 (.05)	≤1	15	0	Poor	2.4
23	3	12	53.1	76.2 +	137.2	63.5	73.7	u	s	0.2	≤8	0	0	Poor	2.0
24	3	12	27.1	44.5 +	74.2	127.0	52.8	s	u	≤.2 (.01)	≤1	0	0	Fair	17.6
25	3	13	30.2	53.1	175.0	91.4	83.6	u	u	0.4	≤8	0	0	Fair	8.5
26	3	13	30.2	35.3	56.5	91.4	34.9	s	u	0.4	≤8	0	0	Fair	5.3
27	3	13	30.2	35 3	111.8	91.4	20.4	u	u	0.4	≤8	0	0	Fair	2.0
28	3	13	50.6	50.6	91.4	147.3	55.9	u	u	0.2	≤8	0	0	Fair	25.4
29	3	14	40.6	20.1	87.6	106.1	18.5	u	u	1.0	≤1	10	0	Poor	11.4
30	3	14	35.7	35.3	57.2	73.7	16.5	s	u	1.0	≤1	15	0	Poor	22.7
31	3	15	43.2	71.1	7.6	142.2	134.6	s	u	3.3	≤8	30	45	Fair	3.5

* parenthesis denotes actual lifting frequency for lifts with frequency of ≤0.2 lifts/min

\+ horizontal distance used in 1981 lifting equation (see Appendix III)

u = upright posture

s = stooped posture

lift only, and three were asymmetrical at both the origin and the destination of the lift. Angle of asymmetry ranged from ten to ninety degrees.

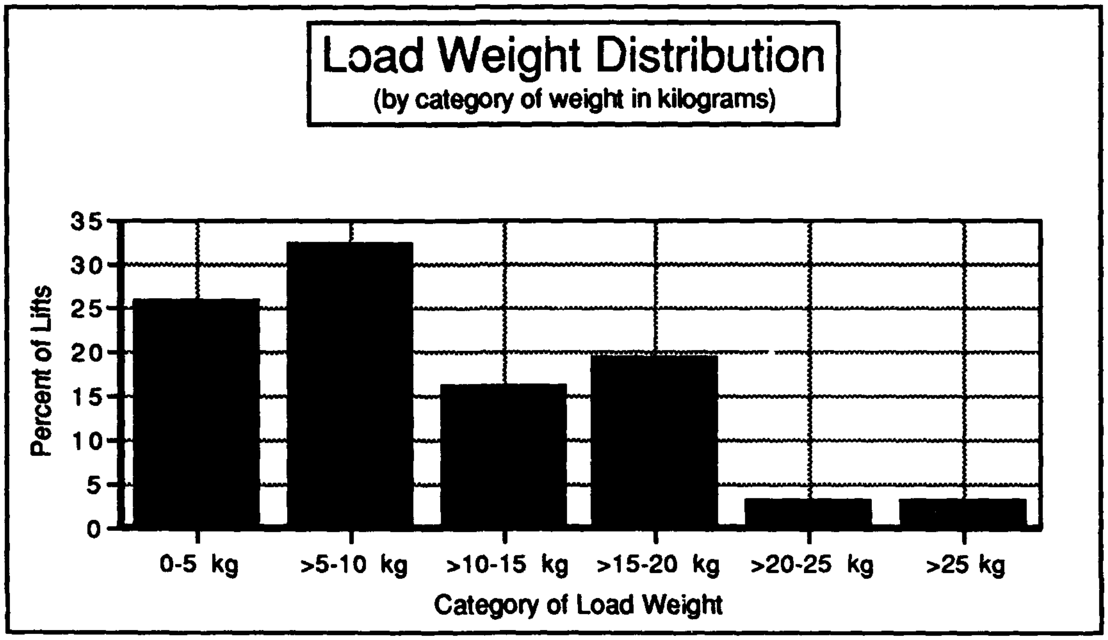


Figure 4. Manual lifting tasks by category of weight lifted.

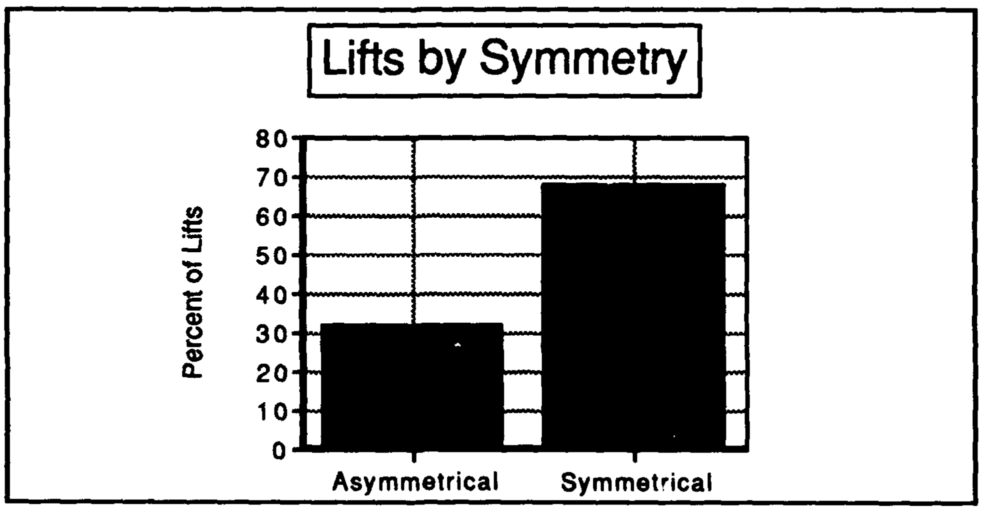


Figure 5. Manual lifting tasks by symmetry of lift.

c. Duration of Lifting Period.

The majority of the lifts (22 of 31, 71.0%) represented manual lifting that a worker does throughout the entire working day (≤8 hours). In Figure 6, the lifts are categorized as ≤8 hours, ≤2 hours, and ≤1 hour duration. These are the three duration categories established in the 1991 Guide. The utility of these categories is discussed further below.

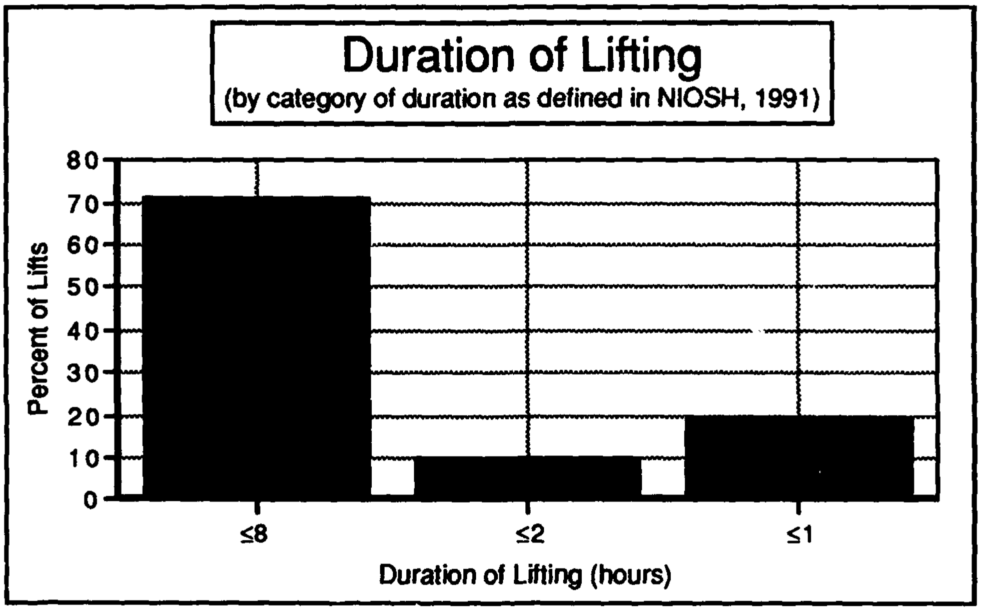


Figure 6. Duration of the manual lifting tasks.

d. Frequency of Lifts.

Lifting frequency, in lifts per minute, ranged from a lift conducted once per day (rounded to .01 minutes) to lifts conducted at a rate of six lifts per minute. Figure 7 depicts the frequency of the lifts analyzed in this study, separated into categories by frequency of lift in lifts per minute.

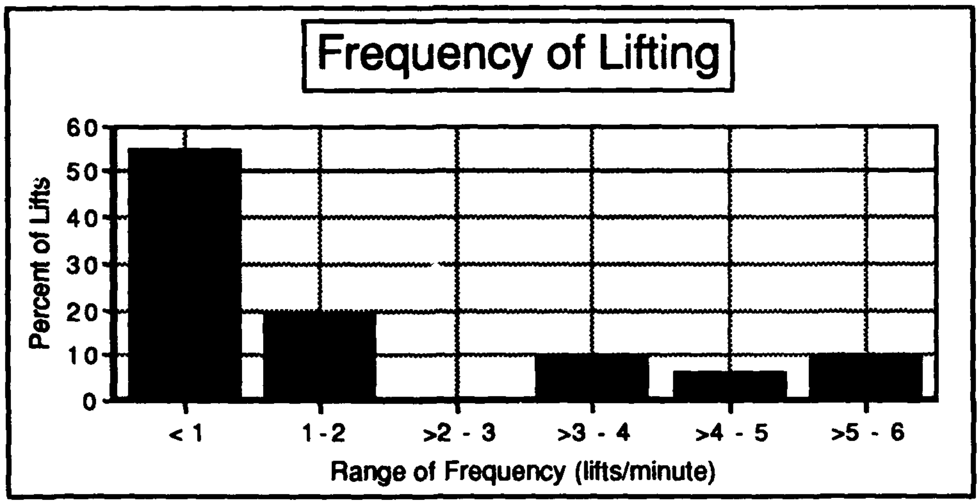
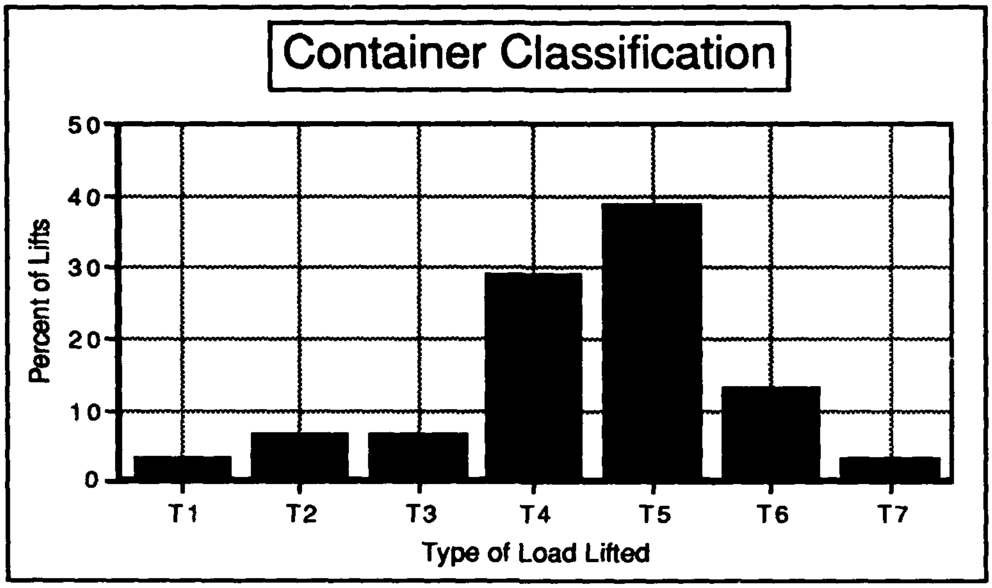


Figure 7. Frequency of lifts by category of frequency.

e. Classification of Load.

The type of load lifted plays an important role in the development of the coupling factor for the 1991 Guide. The presence of handles is a primary factor in the definition of a good hand-to-container coupling as defined by the 1991 lifting equation. Figure 8 depicts the number of lifts for several types of containers. Of 31 lifts, only three containers (9.68%) had handles. Of these, only one worker used the handles in a manner which could be described as a good coupling. "Containers" in this figure refer to rectangular manufactured containers, generally of metal and/or plastic used to hold loads in material handling. Cardboard boxes are a separate category.



LEGEND:

TYPE CONTAINER	DESCRIPTION
T1	Container (handles used)
T2	Container (handles not used)
T3	Container (no handles)
T4	Cardboard Box
T5	Boards, Parts and Misc. Supplies
T6	Roll and Reel Material
T7	Bags

Figure 8. Lifts by type of load lifted.

2. Results of Ergonomic Task Analysis

a. Evaluation Based on the 1981 Guide.

Under the 1981 Guide, only one of the 31 lifts analyzed in this study (3.23%) was found to be not acceptable (weight of load greater than the MPL). Eighteen of the 31 lifts (58.06%) were fully acceptable under the 1981 guidelines. Twelve lifts (38.71%) were acceptable with controls (AWC). The outcome of the analysis for the lifts under the 1981 Guide is shown in Table 6. All lifts, including those lifts that were asymmetrical, have been evaluated using the procedures given in the 1981 Guide.

TABLE 6
WEIGHT LIMITS - 1981 GUIDE

N	Company Number	Job Number	Weight of Load (kg)	HF	VF	DF	FF	AL (kg)	MPL(kg)	Acceptability	Remarks
1	1	1	8.0	0.39	0.81	0.85	1.00	10.7	32.2	A	
2	1	1	6.8	0.30	0.74	1.00	0.99	8.8	26.4	A	Asymmetrical
3	1	1	4.7	0.35	0.84	1.00	1.00	11.8	35.3	A	Asymmetrical
4	1	2	12.2	0.31	0.77	0.91	1.00	8.7	26.1	AWC	
5	1	2	19.6	0.35	0.86	1.00	1.00	12.0	36.1	AWC	
6	1	3	7.3	0.36	0.91	0.87	0.78	8.9	26.7	A	
7	1	3	3.1	0.20	0.96	1.00	0.73	5.6	16.8	A	Asymmetrical
8	1	4	10.2	0.28	0.74	0.96	0.67	5.3	16.0	AWC	
9	1	4	6.8	0.33	0.62	0.80	0.67	4.4	13.2	AWC	Asymmetrical
10	1	5	1.1	0.31	0.91	0.97	0.60	6.6	19.7	A	Asymmetrical
11	1	5	15.4	0.35	0.84	0.93	0.96	10.5	31.5	AWC	Asymmetrical
12	1	6	19.1	0.19	0.95	0.81	0.60	3.5	10.5	NA	
13	1	7	11.2	0.20	0.94	0.90	0.60	4.1	12.2	AWC	
14	1	8	10.7	0.74	0.89	0.85	0.93	20.8	62.5	A	
15	1	8	17.7	0.74	0.81	0.87	0.87	18.1	54.4	A	
16	2	9	6.4	0.48	1.00	1.00	0.93	17.9	53.6	A	
17	2	10	15.4	0.28	0.99	0.93	1.00	10.3	30.9	AWC	
18	2	10	6.4	0.28	0.99	0.84	0.53	4.9	14.8	AWC	
19	2	11	9.1	0.24	0.95	0.96	0.82	7.2	21.5	AWC	
20	2	11	8.2	0.37	0.94	0.96	1.00	13.4	40.1	A	
21	3	12	2.9	0.50	0.83	1.00	1.00	16.6	49.8	A	
22	3	12	2.4	0.19	1.00	0.90	0.99	6.8	20.3	A	Asymmetrical
23	3	12	2.0	0.20	0.75	0.80	0.97	4.7	14.0	A	
24	3	12	17.6	0.38	1.00	0.97	0.84	12.4	37.2	AWC	
25	3	13	8.5	0.50	0.60	0.79	0.97	9.2	27.6	A	
26	3	13	5.3	0.50	0.93	0.92	0.97	16.6	49.8	A	
27	3	13	2.0	0.50	0.85	1.00	0.97	16.5	49.5	A	
28	3	13	25.4	0.30	0.93	0.83	0.99	9.2	27.5	AWC	
29	3	14	11.4	0.37	0.95	1.00	0.94	13.2	39.6	A	Asymmetrical
30	3	14	22.7	0.42	0.93	1.00	0.93	14.5	43.6	AWC	Asymmetrical
31	3	15	3.5	0.35	0.73	0.78	0.76	6.0	18.0	A	Asymmetrical

Lege A = Acceptable
AWC = Acceptable With Controls
NA = Not Acceptable

The analysis of lifts based on the 1981 Guide is influenced by the horizontal distance of the load. Although the 1981 Guide emphasizes the use of the horizontal factor at the origin of the lifting task, the Guide also allows the horizontal distance at the destination of a lift to be used for lifting tasks requiring control of the load at destination of the lift. In 15 of the lifts evaluated, the destination horizontal factor was used to compute the weight limits, as the load required control at the destination. Had the origin horizontal distance been used, the final outcome of six of the fifteen lifts would have been changed to a lesser degree of risk. One of these was the only lift in this study which was unacceptable under the 1981 standard. This lift would have been considered acceptable with controls had the origin horizontal distance been used to evaluate the lift rather than the destination horizontal distance. Decisions made in the analysis of a lift which may have affected the outcome of the evaluation of a lift are detailed in Appendix III.

b. Evaluation Based on the 1991 Guide.

(1) Lift analysis.

The results of the evaluation of the lifting tasks using the 1991 equation is shown in Table 7. Thirteen of the 31 lifts (41.94%) were found to be acceptable when evaluated using the 1991 lifting equation. The last three columns in Table 7 provide the recommended weight limit (RWL), lifting index (LI) and acceptability of the lifting task. The lifting index values ranged from 0.18 to 5.09.

(2) Recommended weight limit values.

The 1991 lift recommended weight limit (RWL) value is established by determining the RWL at the origin and the destination of the lift, then defining the lowest of the two values as the lift RWL. For lifts which do not require exact placement at the destination, the origin RWL is computed and used as the lift RWL. This method replaces the emphasis

TABLE 7

WEIGHT LIMITS - 1991 GUIDE

N	Company Number	Job Number	Weight of Load (kg)	Origin HF	Origin VF	Origin DF	Origin FF	Origin AF	Origin CF	RWL (Origin)	Destination HF	Destination VF	Destination DF	Destination FF	Destination AF	Destination CF	RWL (Dest)	Lift RWL	Lifting Index	Acceptability
1	1	1	8.0	0.98	0.86	0.91	1.00	1.00	1.00	17.6	0.66	0.71	0.91	1.00	1.00	1.00	9.8	9.8	0.82	A
2	1	1	6.8	0.82	0.81	1.00	0.85	1.00	1.00	13.0	0.49	0.81	1.00	0.85	0.90	1.00	7.0	7.0	0.97	A
3	1	1	4.7	0.58	0.88	1.00	1.00	0.86	0.95	9.6	0.58	0.90	1.00	1.00	1.00	0.95	11.4	9.6	0.49	A
4	1	2	12.2	0.76	0.83	0.95	1.00	1.00	1.00	13.8	0.52	0.72	0.95	1.00	1.00	1.00	8.2	8.2	1.49	NA
5	1	2	19.6	0.58	0.90	1.00	1.00	1.00	1.00	12.0	0.66	0.94	1.00	1.00	1.00	1.00	14.3	12.0	1.63	NA
6	1	3	7.3	0.75	0.94	0.91	0.45	1.00	1.00	6.6	0.60	0.79	0.91	0.45	1.00	1.00	4.5	4.5	1.64	NA
7	1	3	3.1	0.34	0.97	1.00	0.45	0.86	0.90	2.6	0.75	0.97	1.00	0.45	0.86	0.90	5.8	2.6	1.17	NA
8	1	4	10.2	0.66	0.80	0.97	0.35	1.00	1.00	4.1	0.47	0.71	0.97	0.35	1.00	1.00	2.6	2.6	3.91	NA
9	1	4	6.8	0.55	0.71	0.88	0.35	0.86	1.00	2.4	0.55	0.95	0.88	0.35	0.90	1.00	3.3	2.4	2.86	NA
10	1	5	1.1	0.60	0.94	0.98	0.27	1.00	1.00	3.4	0.52	0.85	0.98	0.27	0.71	1.00	1.9	1.9	0.58	A
11	1	5	15.4	0.58	0.88	0.96	0.81	1.00	1.00	9.1	0.58	0.98	0.96	0.81	0.95	1.00	9.7	9.1	1.69	NA
12	1	6	19.1	0.79	0.96	0.89	0.75	1.00	1.00	11.6	0.31	0.83	0.89	0.75	1.00	0.95	3.8	3.8	5.09	NA
13	1	7	11.2	0.82	0.95	0.94	0.50	1.00	1.00	8.4	0.33	0.93	0.94	0.50	1.00	0.95	3.2	3.2	3.55	NA
14	1	8	10.7	1.00	0.92	0.91	0.88	1.00	0.90	15.3	Does not require exact placement							15.3	0.70	A
15	1	8	17.7	1.00	0.86	0.92	0.84	1.00	0.90	13.8	Does not require exact placement							13.8	1.28	NA
16	2	9	6.4	0.81	0.87	1.00	0.75	1.00	0.95	11.5	0.86	0.85	1.00	0.75	1.00	1.00	12.6	11.5	0.55	A
17	2	10	15.4	0.81	0.85	1.00	0.75	1.00	1.00	11.9	0.46	0.81	1.00	0.75	1.00	1.00	6.4	6.4	2.40	NA
18	2	10	6.4	0.81	0.85	0.91	0.75	1.00	1.00	10.8	0.47	0.99	0.91	0.75	1.00	0.95	6.9	6.9	0.92	A
19	2	11	9.1	0.58	0.83	0.89	0.81	1.00	1.00	8.0	0.39	0.98	0.89	0.81	1.00	0.95	6.0	6.0	1.51	NA
20	2	11	8.2	1.00	0.82	1.00	0.81	1.00	0.90	13.7	0.62	0.76	1.00	0.81	1.00	0.90	7.9	7.9	1.04	NA
21	3	12	2.9	0.83	0.74	1.00	1.00	1.00	1.00	14.1	0.62	0.67	1.00	1.00	1.00	1.00	9.6	9.6	0.30	A
22	3	12	2.4	0.39	0.86	0.94	1.00	0.95	0.90	6.2	0.32	0.75	0.94	1.00	1.00	0.90	4.7	4.7	0.51	A
23	3	12	2.0	0.47	0.68	0.88	0.85	1.00	0.90	4.9	0.33	0.90	0.88	0.85	1.00	0.90	4.6	4.6	0.43	A
24	3	12	17.6	0.92	0.87	0.91	1.00	1.00	0.95	15.9	0.56	0.71	0.91	1.00	1.00	1.00	8.3	8.3	2.11	NA
25	3	13	8.5	0.83	0.56	0.87	0.81	1.00	1.00	7.5	0.47	0.82	0.87	0.81	1.00	1.00	6.2	6.2	1.36	NA
26	3	13	5.3	0.83	0.92	0.95	0.81	1.00	0.95	12.8	0.71	0.82	0.95	0.81	1.00	1.00	10.3	10.3	0.51	A
27	3	13	2.0	0.83	0.76	1.00	0.81	1.00	1.00	11.8	0.71	0.82	1.00	0.81	1.00	1.00	10.8	10.8	0.18	A
28	3	13	25.4	0.94	0.82	0.90	0.85	1.00	1.00	13.6	0.49	0.65	0.90	0.85	1.00	1.00	5.6	5.6	4.53	NA
29	3	14	11.4	0.62	0.83	1.00	0.94	0.97	0.90	9.7	Does not require exact placement							9.7	1.18	NA
30	3	14	22.7	0.70	0.92	1.00	0.94	0.95	0.90	11.9	Does not require exact placement							11.9	1.91	NA
31	3	15	3.5	0.58	0.93	0.85	0.55	0.90	0.95	5.0	Does not require exact placement							5.0	0.70	A

Legend: A = Acceptable
NA = Not Acceptable

on origin measurements found in the 1981 Guide and eliminates the decision of whether to use destination horizontal measurements rather than origin measurement for lifts requiring control of the load at the destination.

Five of the 31 lifts (16.13%) did not require destination RWL's to be computed. Of the remaining 26 lifting tasks, the destination RWL was lower than the origin RWL in 20 lifting tasks (76.92%). Including those tasks for which a destination RWL was not computed, the origin RWL was used to establish the lift RWL in 11 of 31 lifts (35.48%).

3. Comparison of Task Evaluations.

In Waters, et al., (1993) the authors predict that in some cases the 1991 lifting equation will result lower safe limits for some lifting tasks and higher safe limits for others. A summary of the results the analysis of the lifts for the 1981 and 1991 lifting equations is shown in Table 8. In order the compare the results of the two studies, the RWL and AL values are used. Both limits are the maximum safe limits for lifts considered to pose minimal risk to the majority of the population. As such, these values provide reasonable comparisons of the intent of the two lifting equations, even though the definition of what criteria constitute the minimal level of risk may have changed.

a. Comparison of RWL (1991) and AL (1981) values.

Comparing RWL (1991) to AL (1981) values, in this study, 2 of the 31 lifts (6.45%) resulted in higher limits under the 1991 Guide than the 1981 Guide. One lift (3.23%) produced the same value under both guides. Twenty-eight of the 31 lifts (90.32%) resulted in lower acceptable weight limits under the 1991 Guide than under the 1981 Guide. None of the three tasks with an RWL value that was the same or higher than the task AL value were asymmetrical lifts.

TABLE 8

LIFT ANALYSIS OUTCOMES, 1981 and 1991 LIFTING EQUATIONS

N	Company Number	Job Number	Weight of Load (kg)	NIOSH 1981	AL (kg)	MPL(kg)	NIOSH 1991	Lift RWL	Lifting Index
1	1	1	8.0	A	10.7	32.2	A	9.8	0.82
2*	1	1	6.8	A	8.8	26.4	A	7.0	0.97
3*	1	1	4.7	A	11.8	35.3	A	9.6	0.49
4	1	2	12.2	AWC	8.7	26.1	NA	8.2	1.49
5	1	2	19.6	AWC	12.0	36.1	NA	12.0	1.63
6	1	3	7.3	A	8.9	26.7	NA	4.5	1.64
7*	1	3	3.1	A	5.6	16.8	NA	2.6	1.17
8	1	4	10.2	AWC	5.3	16.0	NA	2.6	3.91
9*	1	4	6.8	AWC	4.4	13.2	NA	2.4	2.86
10*	1	5	1.1	A	6.6	19.7	A	1.9	0.58
11*	1	5	15.4	AWC	10.5	31.5	NA	9.1	1.69
12	1	6	19.1	NA	3.5	10.5	NA	3.8	5.09
13	1	7	11.2	AWC	4.1	12.2	NA	3.2	3.55
14	1	8	10.7	A	20.8	62.5	A	15.3	0.70
15	1	8	17.7	A	18.1	54.4	NA	13.8	1.28
16	2	9	6.4	A	17.9	53.6	A	11.5	0.55
17	2	10	15.4	AWC	10.3	30.9	NA	6.4	2.40
18	2	10	6.4	AWC	4.9	14.8	A	6.9	0.92
19	2	11	9.1	AWC	7.2	21.5	NA	6.0	1.51
20	2	11	8.2	A	13.4	40.1	NA	7.9	1.04
21	3	12	2.9	A	16.6	49.8	A	9.6	0.30
22*	3	12	2.4	A	6.8	20.3	A	4.7	0.51
23	3	12	2.0	A	4.7	14.0	A	4.6	0.43
24	3	12	17.6	AWC	12.4	37.2	NA	8.3	2.11
25	3	13	8.5	A	9.2	27.6	NA	6.2	1.36
26	3	13	5.3	A	16.6	49.8	A	10.3	0.51
27	3	13	2.0	A	16.5	49.5	A	10.8	0.18
28	3	13	25.4	AWC	9.2	27.5	NA	5.6	4.53
29*	3	14	11.4	A	13.2	39.6	NA	9.7	1.18
30*	3	14	22.7	AWC	14.5	43.6	NA	11.9	1.91
31*	3	15	3.5	A	6.0	18.0	A	5.0	0.70

Legend: A = Acceptable
AWC = Acceptable With Controls
NA = Not Acceptable
* denotes asymmetrical lifts

b. Acceptability of Lifting Tasks.

Table 9 shows that more lifts were rated not acceptable when evaluated using the 1991 Guide than when using the 1981 Guide. This table separates the results in to all lifts, symmetrical lifts only, and asymmetrical lifts only. In all cases, fewer lifts were acceptable when evaluated using the 1991 standards. Combining acceptable and AWC lifts from the 1981 analysis of all the lifts, the percent of lifts acceptable dropped from 96.77% using the 1981 equation to 41.94% using the 1991 equation. Looking at only those lifts which met the symmetry assumption of the 1981 equation, the percentage of acceptable lifts went from 52.38% to 38.10%.

Of the 18 lifts which were acceptable (below the AL) under the 1981 standard, 12 (66.67%) were acceptable (lifting index less than one) under the 1991 standard. Six of the 18 lifts (33.33%) which were acceptable under the 1981 standards were rated as not acceptable under the 1991 standard. In contrast, all but one of the 12 lifts which were AWC under the 1981 standards were not acceptable under the 1991 standard. The one lift which was rated acceptable under the 1991 standard had a lifting index value of 0.92, indicating that it is close to the limit for acceptability. The one lift which was unacceptable under the 1981 standard remained unacceptable under the 1991 standard, with the highest lifting index calculated in this study (LI = 5.09).

c. Selection of Horizontal Distance in 1981 Guide Evaluations.

In all cases, the RWL for the 15 lifts evaluated using the destination, rather than the origin, horizontal distance in the 1981 equation was determined by the destination RWL in the 1991 equation. This was an interesting outcome, since the decision to use the destination rather than origin distance was made prior to and independently of the evaluation of the lifts under the 1991 equation. All decisions to use the origin of the lift

TABLE 9

SUMMARY OF LIFT ANALYSIS
1981 and 1991 Guide Evaluations

Tasks Evaluated	NIOSH 1981			NIOSH 1991	
	A	AWC	NA	A	NA
All lifts N=31	18	12	1	13	18
Percent	58.06%	38.71%	3.23%	41.94%	58.06%
	1981 A + AWC =		96.77%	1991 A=	41.94%
Symmetrical lifts N=21	11	9	1	8	13
Percent	52.38%	42.86%	4.76%	38.10%	61.90%
	1981 A + AWC =		47.62%	1991 A=	38.10%
Asymmetrical lifts N=10	7	3	0	5	5
Percent	70.00%	30.00%	0.00%	50.00%	50.00%
	1981 A + AWC =		30.00%	1991 A=	50.00%

Legend: A = Acceptable
AWC = Acceptable with Controls
NA = Not Acceptable

rather than the destination were made based only on the observation of the lift. It was not until the final analysis that the high number of destination horizontal distances used became apparent and the parallels to the 1991 use of destination RWL were observed.

4. The Asymmetry Factor

The ability to evaluate an asymmetrical lift was a major improvement in the 1991 equation. Since many of the lifts in industry are asymmetrical, the addition of this factor to the equation means that one should be able to evaluate more lifts using the 1991 equation

TABLE 10

IMPACT OF ASYMMETRY ON 1981 EVALUATIONS

	Total Lifts	A	Percent A	AWC	Percent AWC	NA	Percent NA
All Lifts	31	18	58.06%	12	38.71%	1	3.23%
Symmetrical Lifts Only	21	11	52.38%	9	42.86%	1	4.76%
Asymmetrical Lifts Only	10	7	70.00%	3	30.00%	0	0.00%

Legend: A = Acceptable
AWC = Acceptable with Controls
NA = Not Acceptable

than the 1981 equation. In this study, ten of 31 (32.23%) lifts were asymmetrical. The 1991 equation was able to evaluate just under fifty percent more lifts than the 1981 equation in this study, indicating that this goal of the 1991 equation will be met.

a. Evaluation of Asymmetrical Lifts Based on the 1981 Guide.

For the purposes of this study, all lifts were evaluated under the 1981 Guide (regardless of asymmetry). Table 10 shows the percentages of lifts that were evaluated as acceptable, acceptable with controls, and not acceptable for all 31 lifts, for only the 21 symmetrical lifts, and for the ten asymmetrical lifts under the 1981 Guide.

b. Impact of Asymmetry on 1981 Guide Values.

Chaffin, et al., (1991) predicted that the addition of an asymmetry factor could reduce the AL and MPL by as much as 40% for asymmetrical lifts. Since other factors also changed, one cannot evaluate the impact the asymmetry factor had on a lift by comparing the 1981 and 1991 results directly. Table 11 analyzes the effect the application of the asymmetry factor from the 1991 Guide to the 1981 lift analysis would have on the outcome of the ten asymmetrical lifts.

TABLE 11

IMPACT OF ASSYMERTY FACTOR ON 1981 EVALUATIONS

N	Weight of Load (kg)	NIOSH 1981	AL (kg)	MPL(kg)	Asymmetry Factor	Revised AL (kg)	Revised MPL (kg)	Percent Change	Revised Acceptability
2	6.8	A	8.8	26.4	0.90	7.9	23.74	-10.0	A
3	4.7	A	11.8	35.3	0.86	10.1	30.34	-14.0	A
7	3.1	A	5.6	16.8	0.86	4.8	14.46	-14.0	A
9	6.8	A	4.4	13.2	0.86	3.8	11.32	-14.0	AWC
10	1.1	A	6.6	19.7	0.71	4.7	13.99	-29.0	A
11	15.4	AWC	10.5	31.5	0.95	10.0	29.92	-5.0	AWC
22	2.4	A	6.8	20.3	0.95	6.4	19.30	-5.0	A
29	11.4	A	13.2	39.6	0.97	12.8	38.46	-3.0	A
30	22.7	AWC	14.5	43.6	0.95	13.8	41.41	-5.0	AWC
31	3.5	A	6.0	18.0	0.90	5.4	16.20	-10.0	A
						Average % change		-10.9	
							Std Dev	7.245	

A = Acceptable
AWC = Acceptable With Controls
NA = Not Acceptable

The outcome of the 1981 equation was multiplied by the largest asymmetry factor (origin or destination) for each of the ten asymmetrical lifts as computed in the 1991 equation. Only asymmetrical lifts are represented in Table 11. The average reduction in the AL and MPL for the lifts was 10.9 percent, with a range of 3 to 29 percent. Only one lift changed in acceptability, moving from acceptable to acceptable with controls. Since the effect of the factors are multiplicative, and the contribution of each factor to the final outcome is independent of the other factors, this approach to the evaluation of the impact of an asymmetry factor on the 1981 lifting equation is reasonable. Throughout this study, the asymmetrical lifts were analyzed using the 1981 equation. It is interesting to note that in only one of ten lifts would the asymmetry of the lift, as evaluated under the 1991 equation, have changed the final results of the 1981 analysis.

c. Angle of Asymmetry.

The angle of asymmetry for the non-sagittal lifts in this study ranged from 10 degrees to 90 degrees. Figure 9 graphically displays the angle of asymmetry at the origin and destination of each asymmetrical lift. The 1991 lifting equation is capable of evaluating asymmetry up to 135 degrees.

5. Duration of a Lifting Task.

Duration of the lifting task (how long the worker does this manual lifting task in the course of the workday) comes in to play as a function of the frequency factor in both the 1981 and the 1991 lifting equations. In the 1981 Guide, only two work durations, 1 hour and 8 hours, are represented. For those jobs that may have durations between those two figures, a choice had to be made which category to use. The 1991 Guide adds a third category, ≤2 hours, to provide evaluation over a greater range of lifting. Only 3 lifts fit

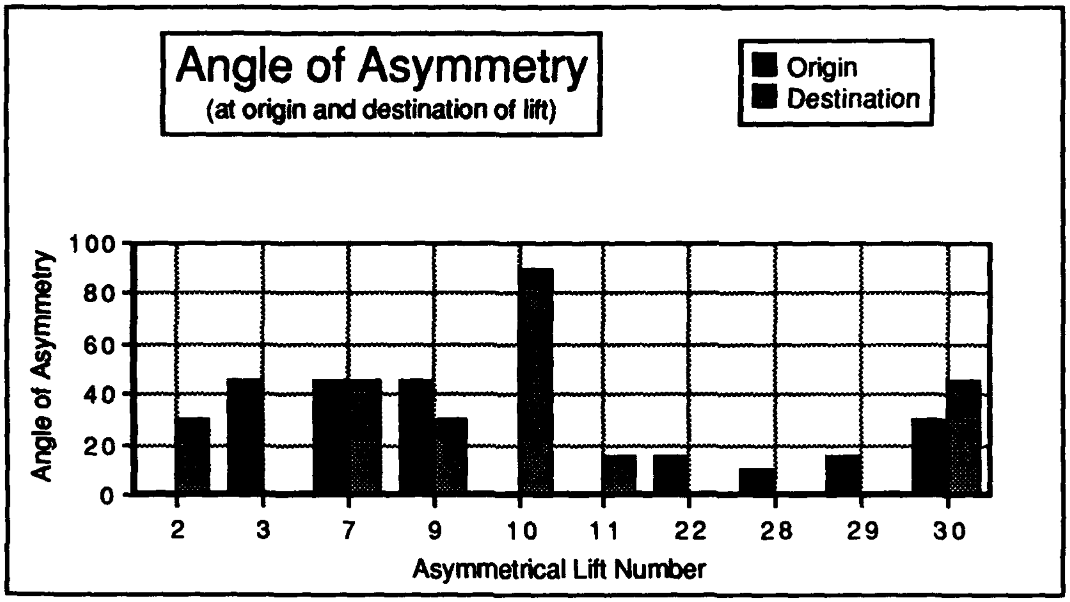


Figure 9. Angle of asymmetry at origin and destination of lift.

into this category. For those three lifts, a better category would have been three or four hours, representing half a work day. Most jobs that are not done for a full work day are done less than an hour. The next natural division would logically be about half of a work day.

None of the three lifts which were counted as ≤2 hours duration (N = 13, 14, and 15) actually had a duration between 1 and 2 hours. Each of these lifts had actual durations of between 3 to 4 hours. (The rationale for the using the category of ≤2 hours duration in the evaluation of these lifts is discussed in Methods and Procedures and Appendix III.)

The available categories were established to utilize the data available from the study of manual lifting in a manner useful for the evaluation of lifts, but the lifting equation has to be in a format useful for industry. The sample size of this study was small, but indicates that the current category of ≤2 hours does not fit the needs of industry for lift evaluation.

6. Coupling Factor

a. Assumption of Good Coupling in 1981 Guide.

The 1981 Guide does not take in to account coupling factor, except to make the assumption that all couplings are "good" couplings. In the 1981 Guide, the assumption of good couplings states "handles, shoes, floor surfaces" as an example of what is meant by good couplings, implying that a load must have handles to be evaluated under the 1981 Guide. Of the 31 lifts evaluated in this study, only three had handles. Of the three, in only one case were the handles used by the worker when handling the load. In this respect, the addition of a coupling factor to account for hand coupling was needed. If good couplings are determined for the 1981 equation as defined in the 1991 equation, then only one of the 31 lifts could be evaluated under the 1981 equation.

b. Assessment of Coupling Factor Based on the 1991 Guide.

Of the 31 lifts in this study, only one was rated as having a good coupling under the 1991 Guide, as shown in Figure 10. The major discriminator in assigning coupling factor was the lack of handles on the load lifted.

c. Weight of Coupling Factor in 1991 Guide.

In developing the coupling factor, it was agreed that less than optimal couplings reduced the lifting capacity, but the degree of the degradation was hard to quantify. Most studies quantified the reduction if the seven to ten percent range. For that reason, the developers of the 1991 equation limited the coupling factor to 0.90, 0.95, or 1.00 (Waters, et. al., 1993). Since the coupling factor is a function not only of the hand-to-load coupling, but also of the vertical distance, some couplings with a fair coupling can receive a value of 1.00. Other fair couplings receive a value of 0.95. All poor couplings are valued

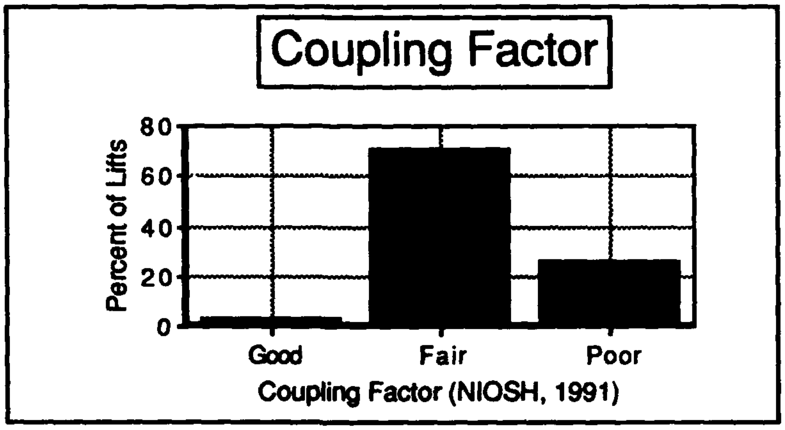


Figure 10. Coupling Factor Percentages

at 0.90. Although only one lift was rated as having a good coupling, 16 of 31 lifts (51.61%) had a coupling factor value of 1.00 in the computation of the lift RWL. Seven lifts (22.58%) had a coupling factor of 0.95 and eight (25.81%) had a coupling factor value of 0.90 (see Figure 11). In only one of the lifts rated as not acceptable based on the 1991 Guide would elimination of the coupling factor from the RWL computation change an unacceptable lift to an acceptable one (N = 20).

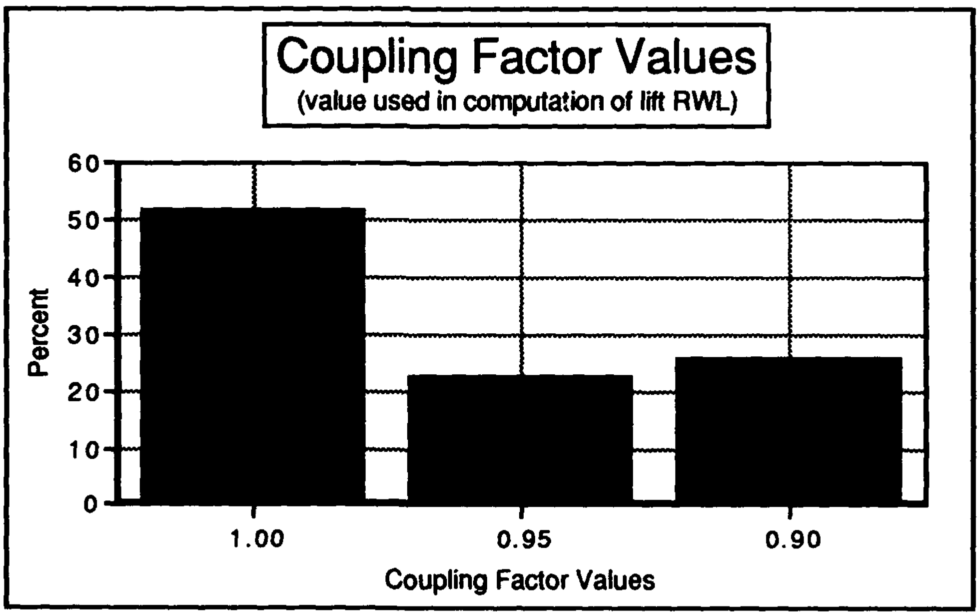


Figure 11. Coupling factor values.

7. The Lifting Index

Evaluation of lifting tasks is to a certain extent an art. Many of the measurements are not exact, as it is difficult to measure distances for a worker in motion, especially when these measurements are dynamic in nature, as in a worker conducting a manual lifting task. The use of workplace measurements and a videotape of the worker in action proved effective in this study, but the measurements cannot be exact. Measurements of the same worker by two evaluators could differ slightly. Measurement of the same worker by the same researcher could also differ. As such, the evaluations of the lifts can only be considered, for the most part, to be an estimation of the outcome of a lift.

a. Utility of the Lifting Index.

Use of the lifting index in the 1991 Guide makes this more visible. In the 1981 Guide, one is comparing the weight of the load to the AL and MPL. It is clear that the weight is above or below one of these indicators. It is not clear, however, the extent to which the lift exceeds or falls below the limit. The lifting index provides a clearer picture of where the lift stands. For example, consider the lifts in Table 12:

TABLE 12

1991 Lifting Index, Selected Lifts

	Weight	1981		1991	
N	of load	AL	MPL	RWL	LI
5	19.6 kg	12.0 kg	36.1 kg	12.0 kg	1.63
19	9.1 kg	7.2 kg	21.5 kg	6.0 kg	1.51

The lifting index allows a quick assessment of how each lift looks in relation to the RWL. Computing a similar lifting index for the 1981 Guide, using (weight of load/AL) allows the two lifts to be more readily compared, as shown in Table 13:

TABLE 13

1981 and 1991 Lifting Indices, Selected Lifts

	Weight	1981			1991	
N	of load	AL	LI	MPL	RWL	LI
5	19.6 kg	12.0 kg	1.63	36.1 kg	12.0 kg	1.63
19	9.1 kg	7.2 kg	1.26	21.5 kg	6.0 kg	1.51

b. Interpretation of the *Lifting* Index Value.

The use of the lifting index to determine the suitability of a lift was discussed in Waters, et al., (1993). Some members of the committee establishing the 1991 lifting equation felt that a lifting index of one still leaves a "substantial fraction" of the population at risk. Other committee members felt that many workers could easily lift a load above a lifting index of one (Waters, et. al., 1993). Most members agreed that a lifting index above three places most workers at risk, although some committee members suggested that the natural selection of workers involved in lifting tasks has resulted in a population generally able to lift above a lifting index of one.

Figure 12 shows the lifts evaluated in this study in categories by lifting index. Four of the 31 lifting tasks (12.90%) had a lifting index greater than 3.0.

Discussions of the differences of opinion in the exact meaning of the lifting index may lead one to see the lifting index grouped into three categories. Lifts with a lifting index below one may be considered acceptable to most of the population. A lifting index between

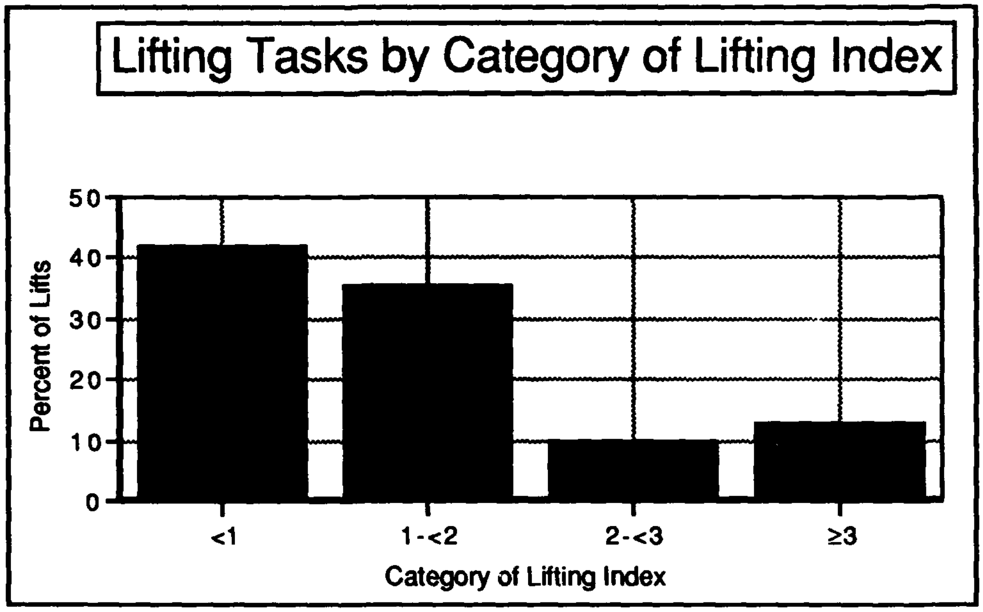


Figure 12. Lifting Tasks by Category of Lifting Index.

1.00 and 3.00 may be acceptable to selected and trained workers. A lifting index above 3.00 would be unacceptable to most of the population. This parallels the 1981 guide categories of below AL, between AL and MPL, and above MPL. Table 14 compares the results of the 1981 and 1991 evaluations in each of these three categories. Viewed this way, the 1991 results more closely parallel the 1981 results than when lifts are evaluated as only above or below a lifting index of 1.00, although the 1991 Guide still resulted in a smaller quantity of acceptable lifts.

8. Injury Data

Up to this point, the results of the 1981 equation have been compared to the results of the 1991 equation. Another comparison which must be made is the comparison of the results of to the injury data available for the lifting tasks. Appendix I contains available injury data pertaining to lifting injuries in the three companies used in this study. A listing

TABLE 14

COMPARISON OF LIFTING INDEX
WITH THE 1981 ACCEPTABILITY CATEGORIES

Lifting Index	<1	1 - <3	>3
Number of Lifts	13	14	4
Percent of Lifts	41.94	45.16	12.90
1981 Acceptability	A	AWC	NA
Number of Lifts	18	12	1
Percent of Lifts	58.06	38.71	3.23

of all injury data collected is in Tables 17 through 20 in Appendix I. Tables 21 through 23 (Appendix I) classify the lifting injuries associated with each job in Companies #1, #2 and #3, respectively, by year. Those lifting injuries which were not associated with one of the jobs reviewed in this study are listed as "Other." Injuries are classified by the part of the body affected in Tables 24 through 26. Those injuries which affected the back are further divided by part of the back affected in Tables 27 through 29.

a. Incidence of Injury.

Injury data was available to the level of job, but not available to the level of an individual lifting task within a job. For each job in this study, the incidence of injury was calculated for each year in which injury data was available. No injuries from lifting were associated with the lifts evaluated in Company #2. Injury data was examined back to 1988 looking for lifting injuries. Therefore, incidence of injury due to lifting for the three jobs evaluated in Company #2 is zero and tables are not provided for this data. Tables 30 through 33 (see Appendix I) provide incidence of injury due to lifting for Companies #1 and #3. Tables 30 and 32 provide incidence of injury rate for all lifting injuries associated with the jobs analyzed in Companies #1 and #3, respectively. These tables include summarized data for reportable and non-reportable injuries. However, non-reportable injury information includes injury reports which may not be as reliable as those for reportable injuries. For that reason, the remainder of this analysis was conducted using injury incidence rates for reportable injuries only (Tables 31 and 33.)

b. Comparison of Injury Data to the Results.

In developing the 1991 equation, the authors adopted the most conservative approach when data based on different criteria conflicted. The multiplicative nature of the 1991 equation resulted in even more conservative values for the recommended loads to be lifted safely. In order to compare the injury data with the recommended load limits produced by the 1981 and 1991 equations, a quantifiable value which would be common to both equations had to be determined. The similarity of the meaning of the RWL and AL values and the utility of the lifting index as a means of measuring the severity of a lift have been discussed previously. To compare the injury data, a common value of the ratio of weight lifted to the maximum weight acceptable to the majority of the workers was used. This, in effect, created a "lifting index 1981" that could be used in comparing injury data. The LI81 value was computed using the ratio of the weight of the load lifted to the AL, in a manner similar to computing the LI for the 1991 equation (LI91). Table 15 shows the calculated values of these lifting indices.

Since the injury data was available at the level of the job, but not for the specific lifting tasks within each job, the highest lifting index value for each job was selected as representative of the risk of injury to a worker. A correlation analysis of the incidence of injury for 1990 and 1991 with the LI81 and LI91 values was conducted. Injury data for

TABLE 15

LIFTING INDEX AND INCIDENCE RATE DATA

Lift Number	Job	LI81	LI91	1990	1991	Average*
1	1	0.75	0.82			
2		0.77	0.97	0.00	0.00	0.00
3		0.30	0.49			
4	2	1.40	1.49			
5		1.63	1.63	1.37	2.87	2.12
6	3	0.82	1.64	1.53	3.19	2.36
7		0.55	1.17			
8	4	1.92	3.91	3.68	5.13	2.01
9		1.54	2.86			
10	5	0.17	0.58			
11		1.47	1.69	40.09	13.98	27.04
12	6	5.45	5.09	64.4	17.82	41.11
13	7	2.73	3.55	17.57	89.13	53.35
14	8	0.51	0.70			
15		0.98	1.28	0.00	36.12	18.06
16	9	0.36	0.55	0.00	0.00	0.00
17	10	1.50	2.40	0.00	0.00	0.00
18		1.31	0.92			
19	11	1.26	1.51	0.00	0.00	0.00
20		0.61	1.04			
21	12	0.17	0.30			
22		0.35	0.51			
23		0.43	0.43			
24		1.42	2.11	0.00	19.05	9.53
25	13	0.92	1.36			
26		0.32	0.51			
27		0.12	0.18			
28		2.76	4.53	0.00	31.10	19.05
29	14	0.86	1.18			
30		1.56	1.91	0.00	0.00	0.00
31	15	0.58	0.70	0.00	17.78	8.89

* average job incidence of injury, 1990 - 1991

TABLE 16

VALUES OF THE PEARSON CORRELATION COEFFICIENT ANALYSIS

		INCIDENCE OF INJURY		AVERAGE
		1990	1991	1990 &1991
LI81	r =	0.76416	0.35229	0.66881
	p =	0.001	NS	0.005
LI91	r =	0.51496	0.40542	0.58478
	p =	0.05	NS	0.02

NS = not significant at $p \leq 0.05$

1992 was not used as the data was not available for a full year. Results of the correlation analysis are shown in Table 16. It can be seen that the Pearson correlation coefficient between the LI81 value and the average of the 1990 and 1991 incidence of injury ($r = 0.67$, $p \leq 0.005$) was higher than the correlation between the LI91 value and the average of the 1990 and 1991 incidence of injury ($r = 0.58$, $p \leq 0.03$).

c. Comparison of 1991 Guide Results to 1981 Guide Results.

A paired t-test of the LI81 and LI91 values for all 31 lifting tasks (see Appendix III) was conducted. The null hypothesis stated that the mean values of the two lifting indices were equal (there was no difference between the LI81 and LI91). The mean value for LI81 was 1.15. The mean value for LI91 was 1.54. The data showed that the null hypothesis can be rejected, and, therefore, two means are not equal. The LI91 is significantly higher than LI81 at $t = 4.223$, $p = 0.0002$. This result indicates that the 1991 equation provides more conservative estimates of the acceptable weights that can be lifted safely than the 1981 equation.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Although this study is limited in scope, many areas for further study an be suggested. It is clear from the data that the 1991 lifting equation produces maximum lifting limits which are lower that the limits calculated by the existing method for the majority of lifts. This may have a severe impact on industry.

In the development of the 1991 equation, the authors, in developing a single model to predict risk of injury from manual lifting, selected the most conservative approach whenever the results of two approaches to assessing the impact of lifting were in conflict (Waters, 1993). This created limits which were generally more conservative than the limits for any one approach. Additionally, by considering the lift at both the origin and destination of a lift, when control was required at the destination, then taking the most conservative of these as the recommended weight limit for the lift, the conservative nature of the 1991 equation is increased.

A goal of the 1991 Guide was to allow the evaluation of a greater number of the lifts found in industry. The data indicates that 1991 equation meets this goal, since over forty percent of the lifts evaluated in this study were asymmetrical and could not be properly evaluated by the 1981 equation. In addition, the number increases more dramatically if one considers hand-to-container coupling. The 1981 Guide makes the assumption of good hand-to-container coupling for a lift to be analyzed. If the definition of a good coupling is that of the 1991 Guide, in only one case was this basic assumption of the 1981 Guide met. This would imply that only one of the 31 lifting tasks could properly be analyzed using the 1981 Guide.

The addition of lifting index is an improvement to the lifting guide of 1981. The intent of the lifting index was to provide "a simple method for comparing the lifting demands associated with different lifting tasks in which the load weights vary and the recommended weight limits (RWL) vary." (Waters, et. al., 1993) The lifting index fulfills this goal. It provides a clear picture of the relative risk associated with a lifting task. The lifting index could be used to prioritize lifts when considering improving lifting conditions.

There is, however, some disagreement among the developers of the 1991 lifting equation as to the exact level of risk conveyed by a lifting index of 1.0. Some feel lifts with lifting index of 1.0 still leave a significant portion of the population at risk of injury. Others feel that a significant portion of the population can perform lifts above a lifting index of 1.0 without injury, possibly as a result of a natural selection of workers involved in lifting tasks. The 1981 Guide, through the use of "layered" limits, allowed consideration of specially screened workers to lift loads which may put others at risk. Since the lifting equations do not directly consider anthropometric characteristics which may revise the level of risk for a given population of workers, tiered consideration of risk reintroduces this type of flexibility to a lifting equation. In all four approaches to evaluating lifting capacity, anthropometry plays an important part. Elimination of anthropometric considerations and worker selection methods may yield too narrow a view of lifting capacity.

The data from this study shows that the 1991 equation produces results which are much more conservative than those produced by the 1981 equation. In addition, the 1991 equation eliminates a method to consider other variables which may modify the assessment of risk. Common sense tells us that a lifting index of 1.0 may be too low for a healthy, young, male worker with no history of injury, but too high for a frail, elderly, female worker with a history of back injury. Human beings come in all different shapes and sizes. One index to cover every worker involved in manual lifting of materials makes the guide easier to use, but coupled with the inherently conservative nature of the 1991 equation, may lack flexibility and be too restrictive for industry.

All three companies involved in this study had access to the 1981 guide, but did not use it. Of two additional companies queried about the use of the guide, only one used the guide for information on design of the workplace. All five of these companies had active safety programs and were making ongoing efforts to improve working conditions. One reason for lack of use of the guide may be that the 1981 Guide offers a lot of information and can be time consuming to study. In addition, the 1981 Guide can be intimidating to a user with limited training in ergonomics. This includes most of the personnel in industry who need to assess the level of risk associated with lifting tasks. Industry needs a straight forward means of assessing the risk of injury to workers, so that the average safety manager, who does not have a background in ergonomics, can make a proper evaluation of risk.

Graphical tables such as those developed in the 1981 Guide should be developed for the 1991 Guide, allowing the evaluator to quickly determine the various factors without needing to do the mathematical computations. Some of the decisions required in the 1981 guide have been eliminated in the 1991 guide, but flow charts and decision templates may also increase the ease of use of the guide. A publication specifically for industry, providing detailed step-by-step analysis procedures may enhance usability of the guide.

The 1991 lifting equation has several improvements over the 1981 lifting equation. The elimination of the tiered approach to lift acceptability and the concept of calculation both the origin and destination RWL then using the most restrictive of these will enhance the ease with which the guide is used in industry. However, consideration should be given to the possibility that the guide is too conservative anD may provide overly restrictive limits to industry.

REFERENCES

Anderson, T. N., (1970). "Human kinetics in Strain Prevention," Journal of Occupational Safety, Vol 8, p248.

Ayoub, M. M., Bethea, N. J., Deivanayagum, S., Asfour, S. S., Bakken, G. M., Liles, D., Mital, A., and Sherif, M., (1978). Determination and Modeling of Lifting Capacity, Final Report, HEW (NIOSH), Grant No. 5R01-OH-05545-02.

Ayoub, M.M., Anil Mital, Shihab S. Asfour, and N. J. Bethea, June, (1980). "Review, Evaluation, and comparison of models for Predicting Lifting Capacity," Human Factors, Vol. 22, No. 3, pp257-269.

Ayoub, M. M., and Anil Mital, (1989). Manual Materials Handling, Taylor and Francis, Philadelphia.

Blow, R. J. and Jackson, J. M., (1971). "Rehabilitation of Registered Dock Workers," Procedings of the Royal Society of Medicine, Vol 64, pp 753-760.

Brown, J. R., (1971). Lifting as an Industrial Hazard, Labour Safety Council, Ontario Department of Labor, Ontario, Canada.

Chaffin, Don B., and Anderson, Gunnar B., (1991). Occupational Biomechanics, John Wiley and Sons, Inc., New York.

Evans, F. G., and Lissner, H. R., (1959). "Biomechanical Studies on the Lumbar Spine and Pelvis," Journal of Bone Joint Surgery, Vol 41A, pp 218-290.

Garg, Arun, and Ayoub, M. M., (1980). "What Criteria Exist for Determining How Much Load Can Be Lifted Safely?," Human Factors, Vol. 22, No. 4, August, pp475-486.

Grandjean, Etienne, (1988). Fitting the Task to the Man. A Textbook of Occupational Ergonomics, 4th Ed, Taylor and Francis.

Knill, Bernie, (April, 1992). "Manual Lifting: Get Ready for the Guidelines," Material Handling, Vol. 47, No. 4, pp. 85-88.

Loesser, T. A., (1979). Low back pain: introduction to planary session. In Advances in Pain Research, Vol. 3, edited by J. J. Bonica, et al., (New York: Raven Press), pp. 631-633.

Metzler, F., (1985). "Epidemiology and statistics in Luxembourg," Ergonomics, Vol 28 No. 1, January, pp. 21 - 24.

Nicholson, A. S., (1985). "Accident Information from Four British Industries," Ergonomics, Vol. 28, No. 1, pp 31-43.

NIOSH. (1981). Work Practices Guide for Manual Lifting, NIOSH Technical Report No. 81-111, US Department of Health and Human Services, National Instiitute for Occupational Safety and Health, Cincinnati, OH.

Putz-Anderson, V., and Waters, T. R. (April, 1991). Revisions in NIOSH guide to manual lifting. Paper presented as national conference entitled "A national strategy for occuptional musculoskeletal injury prevention -- Implementatio issues and research needs." university of Michigan. Ann Arbor, Michigan.

Sonoda, T., (1962). "Studies on the Compression, Tension, and Torsion Strength of the Human Vertebral Column," Journal of the Kyoto Prefect Medical University, Vol. 71, pp 659-702.

Waters, T. R., Garg, A., Putz-Anderson, V., Fine, L. J., (1993). "Revised NIOSH Equation for the design and evaluation of manual lifting tasks," Ergonomics, in press.

APPENDIX I

INJURY AND WORK HOUR DATA

TABLE 17

OSHA REPORTABLE INJURIES, COMPANY #1, JAN 1990 - AUG 1992

DATE	INJURY DESCRIPTION	DEPARTMENT	JOB	REPORTABLE
01/15/90	Strain, low back	3	6	Y
01/16/90	Strain, low back	3	6	Y
01/17/90	Sprain, left wrist	2	4	Y
01/18/90	Strain, left wrist	2	5	Y
01/19/90	Sprain, elbow	2	5	Y
01/19/90	Strain, shoulder and elbow	2	5	Y
02/05/90	Back Strain	3	6	Y
02/26/90	Strain, low back	2	5	Y
03/02/90	Strain, low back	2	3	Y
03/05/90	Strain, right chest muscle	3	6	Y
03/20/90	Back pain	2	3	Y
03/25/90	Strain, low back	2	5	Y
03/26/90	Strain, right wrist	2	5	Y
03/27/90	Strain, upper back	2	2	Y
04/02/90	Strain, low back	2		Y
04/18/90	Strain, back	2	5	Y
04/24/90	Strain, right shoulder	3	6	Y
05/05/90	Strain, low back	2	5	Y
05/07/90	Strain, low back	2		Y
05/14/90	Strain, both wrists	2	5	Y
05/17/90	Strain, low back	2	5	Y
05/21/90	Strain, lower arm	2	5	Y
06/01/90	Strain, left wrist	2	5	Y
06/08/90	Bursitis, right shoulder	2	4	Y
06/12/90	Strain, left chest wall	2		Y
06/29/90	Strain, low back	3	6	Y
07/10/90	Strain, low back	2		Y
07/20/90	Strain, low back	2	4	Y
07/23/90	Strain, left elbow	2	5	Y
07/30/90	Strain, low back	3	6	Y
08/08/90	Sore right elbow	2	5	Y
08/10/90	Strain, low back	2	6	Y
08/19/90	Strain, low back	2		Y
08/24/90	Strain, left shoulder	3	7	Y
08/25/90	Strain, low back	3	6	Y
08/29/90	Strain, left Shoulder	2	5	Y
09/04/90	Strain, low back	2	5	Y
09/05/90	Strain, upper back	2	5	Y
09/06/90	Strain, low back	2		Y
09/24/90	Strain, right arm	2	5	Y
10/05/90	Strain, lower abdomen	3	6	Y
10/08/90	Strain, low back	2	5	Y
11/05/90	Strain, right groin	2	2	Y
11/09/90	Strain, low back	3	6	Y

TABLE 17 (continued)

OSHA REPORTABLE INJURIES, COMPANY #1, JAN 1990 - AUG 1992

DATE	INJURY DESCRIPTION	DEPARTMENT	JOB	REPORTABLE
11/16/90	Strain, low back	2		Y
11/29/90	Strain, left upper arm	2	5	Y
12/07/90	Strain, low back	2	5	Y
01/08/91	Strain, left groin	3	6	Y
01/09/91	Strain, left upper back	3	6	Y
01/17/91	Strain, low back	2	2	Y
02/20/91	Strain, low back	2	2	Y
02/20/91	Strain, low back	2		Y
02/26/91	Strain mid back	2	4	Y
02/27/91	Strain, R forearm, neck and should	2	5	Y
03/02/91	Strain, left upper arm	2	5	Y
03/06/91	Strain, low back	1	8	Y
03/11/91	Strain, low back	2	2	Y
03/25/91	Strain, low back	1	8	Y
03/25/91	strain, right shoulder	3	7	Y
05/01/91	Strain left shoulder	3	7	Y
05/31/91	Strain, low back	1	8	Y
06/06/91	Strain, low back	2	2	Y
06/09/91	Strain, right bicep	2	3	Y
06/17/91	strain, left forearm	3	7	Y
06/27/91	Strain, L shoulder and chest	2	4	Y
07/16/91	Pain left forearm	2	5	Y
07/26/91	Strain, upper back	1		Y
08/06/91	Strain, low back	2	5	Y
08/27/91	Strain, neck and shoulder	2	3	Y
09/09/91	Lumbro sacral strain	2	3	Y
09/20/91	Strain, low back	2	5	Y
09/24/91	Strain, low back	3	7	Y
09/26/91	hernia	3	6	Y
10/01/91	Strain right wrist	2	3	Y
10/15/91	Strain, right forearm	2	5	Y
10/28/91	Pain, left side back	2	4	Y
11/05/91	Lumbro sacral Strain	3	7	Y
11/18/91	pain upper back	2	5	Y
11/25/91	Lumbar strain	2	4	Y
01/07/92	Strain, low back	2	3	Y
01/23/92	Strain, left shoulder	2	2	Y
03/04/92	Strain, low back	3	6	Y
04/24/92	Strain, low back	1		Y
07/20/92	Strain, low back	2	3	Y
07/30/92	Strain, low back	3	6	Y
08/02/92	Strain, low back	2		Y

TABLE 18

NON-REPORTABLE INJURIES, COMPANY #1, JAN 1990 - AUG 1992

DATE	INJURY DESCRIPTION	DEPARTMENT	JOB	REPORTABLE
01/15/90	Back strain	3	6	N
01/16/90	Lower back strain	3	6	N
01/17/90	Low back strain	2	2	N
01/19/90	Right shoulder strain	2	4	N
01/22/90	Strain, left wrist	2	4	N
01/23/90	Strain,lower abdomen	2		N
01/24/90	Strain, arms	2	5	N
01/24/90	CTS	2	5	N
01/30/90	Strained back	2	5	N
02/01/90	Back Strain	2	5	N
02/06/90	Left chest and side strain	3		N
02/19/90	Lower back strain	3	6	N
02/20/90	Wrist hurts	2	4	N
02/21/90	Strain right chest and shoulder	2	5	N
02/26/90	Pain right forearm	3	7	N
02/26/90	Low Back Pain	2	5	N
02/26/90	Right forearm strain	2	4	N
03/05/90	Pulled chest muscles	3		N
03/05/90	Right side of neck hurts	2		N
03/06/90	Strain low back	2	3	N
03/08/90	Strain, chest/right side of body	2	5	N
03/19/90	Lower back strain	3	6	N
03/19/90	Lower back strain	3	6	N
03/19/90	CTS	2	5	N
03/26/90	CTS	2	5	N
03/27/90	Strain. low back	2	2	N
03/29/90	Left arm pain	2	3	N
03/30/90	Strain lower right abdomen/groin	2		N
04/06/90	Low back strain	2		N
04/06/90	Strain right side back	1		N
04/10/90	Strain, lower back	2	4	N
04/12/90	Sore back	1		N
04/19/90	Strain right wrist	2	5	N
04/24/90	Hurt right shoulder	3	6	N
04/25/90	Back Pain	2	5	N
05/02/90	Low back strain	2	3	N
05/02/90	Low back Strain	2	1	N
05/03/90	Twisted knee	2	5	N
05/03/90	Wrist hurting	2		N
05/07/90	Strain, Lower back	2		N
05/11/90	Strain, upper back	2		N
05/14/90	CTS	2	5	N
05/16/90	CTS	2	5	N
05/17/90	Low back strain	2	4	N

TABLE 18 (continued)

NON-REPORTABLE INJURIES, COMPANY #1, JAN 1990 - AUG 1992

DATE	INJURY DESCRIPTION	DEPARTMENT	JOB	REPORTABLE
05/17/90	Low back strain	2	5	N
05/21/90	Strain right chest wall	3	7	N
05/21/90	Pain right arm	2	5	N
05/22/90	Strain left wrist	2	5	N
05/22/90	Pain Lower back	2		N
05/30/90	CTS	2	5	N
05/31/90	Low back strain	2		N
06/01/90	CTS	2	5	N
06/02/90	Strain right wrist	3	7	N
06/08/90	Pain right shoulder	2	3	N
06/12/90	Strain, left side chest wall	2		N
06/13/90	Strain Upper right shoulder	2	5	N
06/18/90	Back pain	2	5	N
06/22/90	CTS	2	5	N
06/28/90	Mid back strain	1		N
06/29/90	Back strain	3	6	N
07/10/90	Strain, pelvic area	2	5	N
07/10/90	Sprain to lower back	2	4	N
07/10/90	Back strain	2		N
07/12/90	Upper right arm strain	1	8	N
07/13/90	CTS	2	5	N
07/13/90	left elbow strain	2	5	N
07/17/90	Back pain	2	5	N
07/19/90	Strain right forearm	2	5	N
07/20/90	Strain posterior neck	2	5	N
07/20/90	Lower back strain	2		N
08/01/90	Right arm hurts	2	3	N
08/01/90	Back strain	2		N
08/02/90	Lower back strain	2	5	N
08/05/90	Strain right wrist	2	5	N
08/08/90	Right elbow and wrist hurting	2	5	N
08/10/90	Lower back strain	2		N
08/15/90	Lower back strain	2	5	N
08/19/90	Lower back strain	2		N
08/22/90	Back pain	2	2	N
08/28/90	Strain, left groin	2		N
09/04/90	Strain lower back/right wrist	2	5	N
09/04/90	Neck pain	2	5	N
09/06/90	Pain right lower back	2		N
09/10/90	Neck hert	2	3	N
09/14/90	Mid back strain	2	5	N
09/25/90	Strain right elbow	2	5	N
09/25/90	Strain right wrist	2	5	N
09/28/90	Pain chest muscles	2	5	N
10/01/90	Sore right arm	2	4	N

TABLE 18 (continued)

NON-REPORTABLE INJURIES, COMPANY #1, JAN 1990 - AUG 1992

DATE	INJURY DESCRIPTION	DEPARTMENT	JOB	REPORTABLE
10/01/90	Sprain left elbow	2	5	N
10/06/90	Back pain	2	2	N
10/09/90	Hurt back	2		N
10/15/90	Left shoulder strain	2	5	N
10/17/90	Pain right lower abdomen	1	8	N
10/19/90	Upper back strain	2	3	N
10/20/90	Strain left wrist	2	5	N
10/30/90	Side hurts	2	3	N
10/31/90	Right wrist pain (CTS)	2	5	N
11/05/90	Strain right groin	2	4	N
11/08/90	Lower back strain	2	2	N
11/16/90	Lower back pain	2		N
11/29/90	Strain upper right arm	2	5	N
11/29/90	Strain left arm	2	5	N
12/05/90	Strain left wrist (CTS)	2	5	N
12/07/90	Back pain	2	3	N
12/10/90	Strain left shoulder	2	4	N
01/08/91	Pain in groin	3	7	N
01/09/91	Pain mid upper back	3	7	N
01/16/91	Low back strain	2	5	N
01/17/91	Strain low back and pain in legs	2	2	N
01/24/91	Sprain left lower back	2		N
01/29/91	Wrist and arm pain	2	2	N
02/05/91	Low back strain	2	2	N
02/19/91	Twisted back	2		N
02/25/91	Sharp back pain	2	2	N
02/26/91	Strain right mid back	2	3	N
02/27/91	Pain right shoulder and upper arm	2	5	N
02/27/91	Pulled back muscle	2	5	N
02/27/91	Sore wrist	2	3	N
03/19/91	Strain left arm	1		N
03/25/91	Back strain	1		N
03/27/91	Pain in shoulder	3	7	N
04/02/91	Strain in shoulder	2		N
04/08/91	Strain low back	2		N
04/23/91	Strain mid back	1		N
04/30/91	Strain right arm and elbow	3	7	N
05/06/91	Strain back of right thigh	2	3	N
05/11/91	Chest muscle strain	2		N
05/13/91	Strain low back	1		N
05/16/91	Strain left shoulder	3	7	N
05/29/91	Tendonitis right elbow	2	4	N
06/05/91	Pain in chest muscles	2	5	N
06/13/91	Strain Left upper arm	3	6	N
06/17/91	Strain left forearm	3	7	N

TABLE 18 (continued)

NON-REPORTABLE INJURIES, COMPANY #1, JAN 1990 - AUG 1992

DATE	INJURY DESCRIPTION	DEPARTMENT	JOB	REPORTABLE
06/17/91	Strain left groin	3	6	N
06/17/91	Strain low back	2	2	N
06/19/91	Pain right bicep	2	4	N
06/27/91	Strain left side of neck	3	7	N
06/28/91	Lower right side back strain	3	7	N
06/28/91	Right upper back strain	2	5	N
07/09/91	Pain left shoulder	2		N
07/10/91	Generalized pain low back	2	3	N
07/16/91	Shooting pain left arm and elbow	2	5	N
07/19/91	Strain low back	2	5	N
07/26/91	Strain right back	1		N
08/08/91	Sprain lower back	3	6	N
08/14/91	Low back strain	3	7	N
08/14/91	Swollen left wrist	2	3	N
08/23/91	Strain left thigh	2	4	N
08/26/91	Pain in lower back	2	3	N
08/27/91	Pain right shoulder	2	3	N
09/04/91	Muscle soreness in abdomen	2	5	N
09/06/91	Strain low back	2	3	N
09/12/91	Pain right shoulder	3	7	N
09/12/91	Low back strain	1		N
09/13/91	Strain left wrist	2	2	N
09/18/91	Strain low back	1	8	N
09/24/91	Low back strain	2	5	N
09/26/91	Strain low back	2	5	N
09/27/91	Strain low back	1	8	N
10/02/91	Low back strain	2	4	N
10/02/91	Strain right wrist	2	3	N
10/08/91	Back pain	3	6	N
10/16/91	Right shoulder strain	2	5	N
10/28/91	Pain in upper back	2	3	N
10/30/91	Pain left scapula	2	3	N
11/05/91	Sprain right wrist	2	4	N
11/06/91	Strain low back	2	5	N
11/08/91	Strain low back	3	7	N
11/18/91	Pain upper right back	2	2	N
11/19/91	Strain, right forearm	2	5	N
11/26/91	Low back strain	2	1	N
11/26/91	Strain upper and mid back	2	5	N
11/27/91	Strain/sprain right elbow	2	2	N
12/03/91	Pain left shoulder	2		N
12/16/91	Pain to lower back	2	3	N
12/16/91	Pain right elbow	2	2	N
12/17/91	Strain low back	1	8	N
01/07/92	Strain, right wrist	2	2	N

TABLE 18 (continued)

NON-REPORTABLE INJURIES, COMPANY #1, JAN 1990 - AUG 1992

DATE	INJURY DESCRIPTION	DEPARTMENT	JOB	REPORTABLE
01/30/92	Strain, left elbow	2	4	N
03/04/92	Strain, Low Back	3	6	N
03/05/92	Strain, Low Back	3		N
03/17/92	Strain, Low Back	1		N
04/02/92	Strain, right side of neck	2		N
04/23/92	Middle back strain	2		N
05/20/92	Sore back	2	5	N
05/26/92	Sore back	2		N
05/29/92	Strain both shoulders	2	5	N
06/02/92	Strain, right groin	1		N
06/19/92	Strain, left low back	2		N
06/29/92	Strain right chest	2	5	N
07/01/92	Strain left side of waist	3	7	N
07/02/92	Strain, right wrist	2	2	N
07/17/92	Strain, Low Back	2	5	N
07/21/92	Strain, Mid back	2	5	N
07/23/92	Strain left testicle	3	6	N
08/03/92	Strain, both elbows	2	5	N
08/14/92	Strain. low back	1		N
08/17/92	Strain, right clavicular area	2	4	N
08/18/92	Strain, left upper arm	3	7	N
08/19/92	Soreness, both wrists	2	5	N
09/02/92	Strain, left Low Back	2	4	N
11/25/92	Back Strain	2	4	N

TABLE 19

INJURY DATA, COMPANY #2, JAN 1988 - AUG 1992

DATE	DESCRIPTION OF INJURY	OSHA REPORTABLE
06/14/88	Muscle strain shoulder	Y
10/26/88	Muscle strain lower back	Y
01/11/89	Strain L Arm	Y
04/19/89	Pain upper back	Y
05/02/89	Pain upper back	Y
05/15/89	Lower back pain	Y
08/15/89	Pain right shoulder and arm	Y
09/20/89	Strain lower back	Y
10/30/89	Strain lower back	Y
01/08/90	Back Strain	Y
02/27/90	Pain upper back	Y
04/25/90	Back Strain	Y
06/18/90	Strain groin muscle	Y
08/30/90	Pain groin area	Y
11/05/90	strain lower back	Y
12/23/90	Muscle strain back	Y
06/26/92	Strain, low back	Y
07/13/92	Strain, low back	Y
07/13/92	Strain, low back	Y
09/09/92	Strain, left bicep and forearm	Y
07/14/89	pain right arm and shoulder	N
07/17/90	Strain back muscle	N
08/03/90	Strain left shoulder and arm	N
09/12/90	pain right shoulder	N
02/14/91	Pain right arm and back	N

(There were no injuries due to lifting for the jobs reviewed in this study.)

TABLE 20

INJURY DATA, COMPANY #3, JAN 1990 - AUG 1992

DATE	DESCRIPTION OF INJURY	DEPARTMENT	JOB	REPORTABLE
01/02/90	back strain	1		N
03/15/90	Back pain	6		N
04/02/90	Stiff neck	3	15	N
05/27/90	back pain	4	14	N
08/22/90	Strained back	6		N
09/25/90	Low back pain	2		N
11/07/90	pain, left buttock	4		N
01/17/91	Back pain	1		N
01/17/91	Pain left shoulder and neck	6		N
02/11/91	Back Pain	6		N
02/21/91	Pulled muscle, right groin	6	13	N
03/03/91	pain, lower back	3		N
03/19/91	Stiffness in back and right neck	1		N
03/20/91	Tenderness, right shoulder	6		N
04/11/91	Stiff back	6		N
04/20/91	low back pain	6		N
05/13/91	Strained muscle in back	1		N
05/16/91	back pain	3		N
05/23/91	back pain	5		N
06/13/91	Sprained muscle in back	1		N
06/24/91	Strained right shoulder	2		N
06/28/91	Pulled muscle, mid back	6		N
07/01/91	Pain right lumbar area	2		N
07/13/91	pulled muscle, R lateral abdomen	6		N
08/30/91	Sprained muscle right back	5		N
09/05/91	Pulled muscle, right arm	6		N
09/12/91	Back Pain	6		N
09/29/91	Pulled back muscle	4		N
10/02/91	Pulled muscle in neck	6		N
11/27/91	Pain in left gluteus maximus	1		N
12/05/91	Pain, left side mid back	5		N
12/17/91	Pain, back muscles	6		N
12/20/91	back pain	5		N
01/04/92	pain, left Groin	6		N
01/04/92	Pulled muscle, left belt line	6		N
01/14/92	Pain, right sacral area	1		N
01/15/92	Back pain, left belt line	6		N
01/21/92	Back pain	5		N
02/05/92	Pain, lower back and right knee	1		N
02/13/92	pain, left shoulder blade	5		N
02/28/92	back pain	4	15	N
03/11/92	Pain, mid lumbar area	4	15	N
03/21/92	Back pain	2	15	N
03/22/92	Pain, lower left back	2		N

TABLE 20 (continued)

INJURY DATA, COMPANY #3, JAN 1990 - AUG 1992

DATE	DESCRIPTION OF INJURY	DEPARTMENT	JOB	REPORTABLE
04/23/92	Pain, left mid back	4		N
05/01/92	Torn bicep, left shoulder	4		N
05/07/92	Pain, mid back	6		N
05/13/92	Back Pain	6		N
07/13/92	Low back pain	1	15	N
07/16/92	low back pain	6		N
07/26/92	Pain, left shoulder	1		N
08/06/92	Pain, left trapezius	2		N
08/22/92	pain, left shoulder	6		N
08/27/92	back pain	2		N
01/08/90	Low back pain	6		Y
02/11/90	Strain chest muscle	4		Y
03/10/90	Back pain	1		Y
07/02/90	back injury	6		Y
07/17/90	back injury	6		Y
08/01/90	Sprain/strain right groin muscle	4		Y
08/20/90	Strain, low back	6		Y
09/11/90	Acute lumbar sprain	4		Y
09/14/90	Back pain and stiff neck	3		Y
09/19/90	Pain, lower back and neck	3		Y
09/19/90	Back Strain	3		Y
09/26/90	Low back and hip pain	1		Y
10/07/90	Strained back	2		Y
12/03/90	Strained Back muscle	3		Y
01/12/91	Strained back muscle	2		Y
02/07/91	Muscle strain, left shoulder	2		Y
02/25/91	Low back pain	5		Y
03/22/91	Muscle Strain, back	5		Y
03/27/91	Pulled muscle, lower back	4	15	Y
04/12/91	Pulled muscle, right arm	4	15	Y
04/12/91	Pain in upper arm	6	13	Y
07/22/91	Muscle sprain, back	6		Y
09/04/91	Mid shoulder and back pain	4		Y
09/10/91	Muacle strain, back	6	12	Y
09/10/91	Back pain	3		Y
10/21/91	Pain, lower right back	6		Y
11/06/91	Strained chest/back muscles	6		Y
12/05/91	Pulled muscle, left shoulder	3		Y
01/29/92	Right shoulder strain	4		Y
03/03/92	pain left iliuma and 3 lumbar	3		Y
03/17/92	back Pain	4	15	Y
04/03/92	Pain, right groin	1		Y
05/16/92	Lower back pain	5		Y
06/01/92	Lumbar sprain/strain	3		Y

TABLE 20 (continued)

INJURY DATA, COMPANY #3, JAN 1990 - AUG 1992

DATE	DESCRIPTION OF INJURY	DEPARTMENT	JOB	REPORTABLE
06/03/92	left neck pain	3		Y
06/06/92	low back pain	6		Y
06/15/92	Strained muscle, lower left back	1	15	Y
06/21/92	Pulled muscle, neck	3		Y
06/27/92	pain upper and lower back	3		Y
07/13/92	Pulled muscle, right shoulder	6	12	Y
07/14/92	Low back pain	2	15	Y
07/15/92	Back pain	2		Y
07/15/92	Back pain	3		Y
07/26/92	Pain, left mid back	6	15	Y

TABLE 21

INJURIES DUE TO LIFTING, COMPANY #1
(ALL TYPES OF INJURIES)

Company 1	NON-REPORTABLE INJURIES					OSHA REPORTABLE INJURIES					TOTAL INJURIES				
	1990	1991	1992	TOTAL	Percent	1990	1991	1992	TOTAL	Percent	1990	1991	1992	TOTAL	Percent
Job 1	1	1	0	2	0.99	0	0	0	0	0.00	1	1	0	2	0.69
Job 2	5	9	2	16	7.88	2	4	1	7	8.14	7	13	3	23	7.96
Job 3	9	12	0	21	10.34	2	4	2	8	9.30	11	16	2	29	10.03
Job 4	10	5	4	19	9.36	3	4	0	7	8.14	13	9	4	26	9.00
Job 5	45	14	7	66	32.51	21	7	0	28	32.56	66	21	7	94	32.53
Job 6	7	4	2	13	6.40	11	3	2	16	18.60	18	7	4	29	10.03
Job 7	3	11	2	16	7.88	1	5	0	6	6.98	4	16	2	22	7.61
Job 8	2	3	0	5	2.46	0	3	0	3	3.49	2	6	0	8	2.77
Other	24	13	8	45	22.17	7	2	2	11	12.79	31	15	10	56	19.38
TOTAL	106	72	25	203	100.00	47	32	7	86	100.00	153	104	32	289	100.00
Percent of Total	52.22	35.47	12.32	100.00		54.65	37.21	8.14	100.00		52.94	35.99	11.07	100.00	

TABLE 22

INJURIES DUE TO LIFTING, COMPANY #2
(ALL TYPES OF INJURIES)

Company 2	NON-REPORTABLE INJURIES						OSHA REPORTABLE INJURIES						TOTAL INJURIES					
	1988	1989	1990	1991	1992	TOTAL	1988	1989	1990	1991	1992	TOTAL	1988	1989	1990	1991	1992	TOTAL
Job 9	no injuries due to lifting																	
Job 10	no injuries due to lifting																	
Job 11	no injuries due to lifting																	
Other	0	1	3	1	0	5	2	7	7	0	4	20	2	8	10	1	4	25
TOTAL	0	1	3	1	0	5	2	7	7	0	4	20	2	8	10	1	4	25
Percent of Total	0	20	60	20	0	100	10	35	35	0	20	100	8	32	40	4	16	100

TABLE 23

INJURIES DUE TO LIFTING, COMPANY #3
(ALL TYPES OF INJURIES)

Company 3	NON-REPORTABLE INJURIES					OSHA REPORTABLE INJURIES					TOTAL INJURIES				
	1990	1991	1992	TOTAL	Percent	1990	1991	1992	TOTAL	Percent	1990	1991	1992	TOTAL	Percent
Job 12	0	0	0	0	0.00	0	1	1	2	4.26	0	1	1	2	2.04
Job 13	0	1	0	1	1.96	0	1	0	1	2.13	0	2	0	2	2.04
Job 14	1	0	0	1	1.96	0	0	0	0	0.00	1	0	0	1	1.02
Job 15	1	0	4	5	9.80	0	2	4	6	12.77	1	2	8	11	11.22
Other	14	25	5	44	86.27	11	10	17	38	80.85	25	35	22	82	83.67
TOTAL	16	26	9	51	100.00	11	14	22	47	100.00	27	40	31	98	100.00
Percent of Total	31.37	50.98	17.65	100.00		23.40	29.79	46.81	100.00		27.55	40.82	31.63	100.00	

TABLE 24

INJURIES BY PART OF BODY AFFECTED, COMPANY #1

NON-REPORTABLE INJURIES

	Back	Shoulder/ Neck	Arm/ Elbow	Wrist*	Legs	Torso**	TOTAL	Percent of TOTAL
Job 1	2	0	0	0	0	0	2	0.99
Job 2	10	0	3	3	0	0	16	7.88
Job 3	11	3	2	3	1	1	21	10.34
Job 4	6	2	5	3	1	2	19	9.36
Job 5	22	8	11	18	1	6	66	32.51
Job 6	9	1	1	0	0	2	13	6.40
Job 7	4	4	4	1	0	3	16	7.88
Job 8	3	0	1	0	0	1	5	2.46
Other Jobs	30	5	1	1	0	8	45	22.17
TOTAL	97	23	28	29	3	23	203	
Percent of Total	47.78	11.33	13.79	14.29	1.48	11.33		

REPORTABLE INJURIES

	Back	Shoulder/ Neck	Arm/ Elbow	Wrist*	Legs	Torso**	TOTAL	Percent of TOTAL
Job 1	0	0	0	0	0	0	0	0.00
Job 2	5	1	0	0	0	1	7	8.14
Job 3	5	1	1	1	0	0	8	9.30
Job 4	4	2	0	1	0	0	7	8.14
Job 5	12	3	9	4	0	0	28	32.56
Job 6	11	1	0	0	0	4	16	18.60
Job 7	2	3	1	0	0	0	6	6.98
Job 8	3	0	0	0	0	0	3	3.49
Other Jobs	10	0	0	0	0	1	11	12.79
TOTAL	52	11	11	6	0	6	86	
Percent of Total	60.47	12.79	12.79	6.98	0.00	6.98		

ALL INJURIES (TOTAL REPORTABLE AND NON-REPORTABLE)

	Back	Shoulder/ Neck	Arm/ Elbow	Wrist*	Legs	Torso**	TOTAL	Percent of TOTAL
Job 1	2	0	0	0	0	0	2	0.69
Job 2	15	1	3	3	0	1	23	7.96
Job 3	16	4	3	4	1	1	29	10.03
Job 4	10	4	5	4	1	2	26	9.00
Job 5	34	11	20	22	1	6	94	32.53
Job 6	20	2	1	0	0	6	29	10.03
Job 7	6	7	5	1	0	3	22	7.61
Job 8	6	0	1	0	0	1	8	2.77
Other Jobs	40	5	1	1	0	9	56	19.38
TOTAL	149	34	39	35	3	29	289	
Percent of Total	51.56	11.76	13.49	12.11	1.04	10.03		

* Wrist includes Carpal Tunnel Syndrome

** Torso includes injuries to the chest, sides, abdomen, buttock and groin areas.

TABLE 25

INJURIES BY PART OF BODY AFFECTED, COMP NY #2

NON-REPORTABLE INJURIES

	Back	Shoulder/ Neck	Arm/ Elbow	Wrist*	Legs	Torso**	TOTAL	Percent of TOTAL
Job 9	0	0	0	0	0	0	0	0.00
Job 10	0	0	0	0	0	0	0	0.00
Job 11	0	0	0	0	0	0	0	0.00
Other Jobs	2	3	0	0	0	0	5	100.00
TOTAL	2	3	0	0	0	0	5	
Percent of Total	40.00	60.00	0.00	0.00	0.00	0.00		

REPORTABLE INJURIES

	Back	Shoulder/ Neck	Arm/ Elbow	Wrist*	Legs	Torso**	TOTAL	Percent of TOTAL
Job 9	0	0	0	0	0	0	0	0.00
Job 10	0	0	0	0	0	0	0	0.00
Job 11	0	0	0	0	0	0	0	0.00
Other Jobs	14	2	2	0	0	2	20	100.00
TOTAL	14	2	2	0	0	2	20	
Percent of Total	70.00	10.00	10.00	0.00	0.00	10.00		

ALL INJURIES (TOTAL REPORTABLE AND NON-REPORTABLE)

	Back	Shoulder/ Neck	Arm/ Elbow	Wrist*	Legs	Torso**	TOTAL	Percent of TOTAL
Job 9	0	0	0	0	0	0	0	0.00
Job 10	0	0	0	0	0	0	0	0.00
Job 11	0	0	0	0	0	0	0	0.00
Other Jobs	16	5	2	0	0	2	25	100.00
TOTAL	16	5	2	0	0	2	25	
Percent of Total	64.00	20.00	8.00	0.00	0.00	8.00		

* Wrist includes Carpal Tunnel Syndrome

** Torso includes injuries to the chest, sides, abdomen, buttock and groin areas.

TABLE 26

INJURIES BY PART OF BODY AFFECTED, COMPANY #3

NON-REPORTABLE INJURIES

	Back	Shoulder/ Neck	Arm/ Elbow	Wrist*	Legs	Torso**	TOTAL	Percent of TOTAL
Job 12	0	0	0	0	0	0	0	0.00
Job 13	0	0	0	0	0	1	1	1.85
Job 14	1	0	0	0	0	0	1	1.85
Job 15	4	1	0	0	0	0	5	9.26
Other Jobs	33	8	2	0	0	4	47	87.04
TOTAL	38	9	2	0	0	5	54	
Percent of Total	70.37	16.67	3.70	0.00	0.00	9.26		

REPORTABLE INJURIES

	Back	Shoulder/ Neck	Arm/ Elbow	Wrist*	Legs	Torso**	TOTAL	Percent of TOTAL
Job 12	1	1	0	0	0	0	2	4.55
Job 13	0	0	1	0	0	0	1	2.27
Job 14	0	0	0	0	0	0	0	0.00
Job 15	5	0	1	0	0	0	6	13.64
Other Jobs	27	5	0	0	0	3	35	79.55
TOTAL	33	6	2	0	0	3	44	
Percent of Total	75.00	13.64	4.55	0.00	0.00	6.82		

ALL INJURIES (TOTAL REPORTABLE AND NON-REPORTABLE)

	Back	Shoulder/ Neck	Arm/ Elbow	Wrist*	Legs	Torso**	TOTAL	Percent of TOTAL
Job 12	1	1	0	0	0	0	2	2.04
Job 13	0	0	1	0	0	1	2	2.04
Job 14	1	0	0	0	0	0	1	1.02
Job 15	9	1	1	0	0	0	11	11.22
Other Jobs	60	13	2	0	0	7	82	83.67
TOTAL	71	15	4	0	0	8	98	
Percent of Total	72.45	15.31	4.08	0.00	0.00	8.16		

* Wrist includes Carpal Tunnel Syndrome

** Torso includes injuries to the chest, sides, abdomen, buttock and groin areas.

TABLE 27

BACK INJURIES BY PART OF BACK, COMPANY #1

NON-REPORTABLE BACK INJURIES

	Lower Back	% of Lower Back Injuries	Mid Back	% of Mid Back Injuries	Upper Back	% of Upper Back Injuries	Generalized or Unspecified	% of General Back Injuries	Total Back Injuries	Percent of Total Back
Job 1	2	3.39	0	0.00	0	0.00	0	0.00	2	2.06
Job 2	6	10.17	0	0.00	1	14.29	3	12.50	10	10.31
Job 3	6	10.17	1	14.29	3	42.86	1	4.17	11	11.34
Job 4	5	8.47	0	0.00	0	0.00	1	4.17	6	6.19
Job 5	11	18.64	2	28.57	2	28.57	7	29.17	22	22.68
Job 6	6	10.17	0	0.00	0	0.00	3	12.50	9	9.28
Job 7	3	5.08	1	14.29	0	0.00	0	0.00	4	4.12
Job 8	3	5.08	0	0.00	0	0.00	0	0.00	3	3.09
Other Jobs	17	28.81	3	42.86	1	14.29	9	37.50	30	30.93
TOTAL	59	100.00	7	100.00	7	100.00	24	100.00	97	
Percent of Total	60.82		7.22		7.22		24.74		100	

OSHA REPORTABLE BACK INJURIES

	Lower Back	% of Lower Back Injuries	Mid Back	% of Mid Back Injuries	Upper Back	% of Upper Back Injuries	Generalized or Unspecified	% of General Back Injuries	Total Back Injuries	Percent of Total Back
Job 1	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Job 2	4	9.52	0	0.00	1	25.00	0	0.00	5	9.62
Job 3	4	9.52	0	0.00	0	0.00	1	25.00	5	9.62
Job 4	2	4.76	1	50.00	0	0.00	1	25.00	4	7.69
Job 5	9	21.43	0	0.00	2	50.00	1	25.00	12	23.08
Job 6	9	21.43	1	50.00	0	0.00	1	25.00	11	21.15
Job 7	2	4.76	0	0.00	0	0.00	0	0.00	2	3.85
Job 8	3	7.14	0	0.00	0	0.00	0	0.00	3	5.77
Other Jobs	9	21.43	0	0.00	1	25.00	0	0.00	10	19.23
TOTAL	42	100.00	2	100.00	4	100.00	4	100.00	52	
Percent of Total	80.77		3.85		7.69		7.69		100	

OVERALL BACK INJURIES

	Lower Back	% of Lower Back Injuries	Mid Back	% of Mid Back Injuries	Upper Back	% of Upper Back Injuries	Generalized or Unspecified	% of General Back Injuries	Total Back Injuries	Percent of Total Back
Job 1	2	1.98	0	0.00	0	0.00	0	0.00	2	1.34
Job 2	10	9.90	0	0.00	2	18.18	3	10.71	15	10.07
Job 3	10	9.90	1	11.11	3	27.27	2	7.14	16	10.74
Job 4	7	6.93	1	11.11	0	0.00	2	7.14	10	6.71
Job 5	20	19.80	2	22.22	4	36.36	8	28.57	34	22.82
Job 6	15	14.85	1	11.11	0	0.00	4	14.29	20	13.42
Job 7	5	4.95	1	11.11	0	0.00	0	0.00	6	4.03
Job 8	6	5.94	0	0.00	0	0.00	0	0.00	6	4.03
Other Jobs	26	25.74	3	33.33	2	18.18	9	32.14	40	26.85
TOTAL	101	100.00	9	100.00	11	100.00	28	100.00	149	100.00
Percent of Total	67.79		6.04		7.38		18.79		100.00	

TABLE 28

BACK INJURIES BY PART OF BACK, COMPANY #2

NON-REPORTABLE BACK INJURIES

	Lower Back	% of Lower Back Injuries	Mid Back	% of Mid Back Injuries	Upper Back	% of Upper Back Injuries	Generalized or Unspecified	% of General Back Injuries	Total Back Injuries	Percent of Total Back
Job 9	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Job 10	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Job 11	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Other Jobs	0	0.00	0	0.00	0	0.00	2	100.00	2	100.00
TOTAL	0	0.00	0	0.00	0	0.00	2	100.00	2	100.00
Percent of Total	0.00		0.00		0.00		100.00		100	

OSHA REPORTABLE BACK INJURIES

	Lower Back	% of Lower Back Injuries	Mid Back	% of Mid Back Injuries	Upper Back	% of Upper Back Injuries	Generalized or Unspecified	% of General Back Injuries	Total Back Injuries	Percent of Total Back
Job 9	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Job 10	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Job 11	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Other Jobs	8	100.00	0	0.00	3	100.00	3	100.00	14	100.00
TOTAL	8	100.00	0	0.00	3	100.00	3	100.00	14	100.00
Percent of Total	57.14		0.00		21.43		21.43		100	

OVERALL BACK INJURIES

	Lower Back	% of Lower Back Injuries	Mid Back	% of Mid Back Injuries	Upper Back	% of Upper Back Injuries	Generalized or Unspecified	% of General Back Injuries	Total Back Injuries	Percent of Total Back
Job 9	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Job 10	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Job 11	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Other Jobs	8	100.00	0	0.00	3	100.00	5	100.00	16	100.00
TOTAL	8	100.00	0	0.00	3	100.00	5	100.00	16	100.00
Percent of Total	50.00		0.00		18.75		31.25		100.00	

TABLE 29

BACK INJURIES BY PART OF BACK, COMPANY #3

NON-REPORTABLE BACK INJURIES

	Lower Back	% of Lower Back Injuries	Mid Back	% of Mid Back Injuries	Upper Back	% of Upper Back Injuries	Generalized or Unspecified	% of General Back Injuries	Total Back Injuries	Percent of Total Back
Job 12	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Job 13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Job 14	0	0.00	0	0.00	0	0.00	1	4.55	1	2.63
Job 15	2	22.22	0	0.00	0	0.00	2	9.09	4	10.53
Other Jobs	7	77.78	6	100.00	1	100.00	19	86.36	33	86.84
TOTAL	9	100.00	6	100.00	1	100.00	22	100.00	38	100.00
Percent of Total	23.68		15.79		2.63		57.89		100	

OSHA REPORTABLE BACK INJURIES

	Lower Back	% of Lower Back Injuries	Mid Back	% of Mid Back Injuries	Upper Back	% of Upper Back Injuries	Generalized or Unspecified	% of General Back Injuries	Total Back Injuries	Percent of Total Back
Job 12	0	0.00	0	0.00	0	0.00	1	6.25	1	3.03
Job 13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Job 14	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Job 15	3	20.00	1	100.00	0	0.00	1	6.25	5	15.15
Other Jobs	12	80.00	0	0.00	1	100.00	14	87.50	27	81.82
TOTAL	15	100.00	1		1		16		33	
Percent of Total	45.45		3.03		3.03		48.48		100	

OVERALL BACK INJURIES

	Lower Back	% of Lower Back Injuries	Mid Back	% of Mid Back Injuries	Upper Back	% of Upper Back Injuries	Generalized or Unspecified	% of General Back Injuries	Total Back Injuries	Percent of Total Back
Job 12	0	0.00	0	0.00	0	0.00	1	2.63	1	1.41
Job 13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Job 14	0	0.00	0	0.00	0	0.00	1	2.63	1	1.41
Job 15	5	20.83	1	14.29	0	0.00	3	7.89	9	12.68
Other Jobs	19	79.17	6	85.71	2	100.00	33	86.84	60	84.51
TOTAL	24	100.00	7	100.00	2	100.00	38	100.00	71	100.00
Percent of Total	33.80		9.86		2.82		53.52		100.00	

TABLE 30

INCIDENCE OF INJURY DUE TO LIFTING (ALL INJURIES), COMPANY #1

	1990			1991			1992*			Acceptability of Task	
	Work Hours	Number Injuries	Incidence Rate	Work Hours	Number Injuries	Incidence Rate	Work Hours	Number Injuries	Incidence Rate**	1981	1991
Job 1	472036	1	0.42	451333	1	0.44	296432	0	0.00		
Task 1										A	A
Task 2***										A	A
Task 3***										A	A
Job 2	291212	7	4.81	278440	13	9.34	182877	3	2.19		
Task 4										AWC	NA
Task 5										AWC	NA
Job 3	262210	11	8.39	250709	16	12.76	164664	2	1.62		
Task 6										A	NA
Task 7***										A	NA
Job 4	163067	13	15.94	155915	9	11.54	102404	4	5.21		
Task 8										AWC	NA
Task 9***										AWC	NA
Job 5	104765	66	126.00	100171	21	41.93	65791	7	14.19		
Task 10***										A	A
Task 11***										AWC	NA
Job 6 (Task 12)	34161	18	105.38	33677	7	41.57	22277	4	23.94	NA	NA
Job 7 (Task 13)	11380	4	70.30	11219	16	285.23	7420	2	35.94	AWC	NA
Job 8	18682	2	21.41	16613	6	72.23	10398	0	0.00		
Task 14										A	A
Task 15										A	NA

Legend: A = Acceptable
AWC = Acceptable with Controls
NA = Not Acceptable

* through August, 1992
**based on 133,333.3 hours
*** denotes asymmetrical lifts

TABLE 31

INCIDENCE OF INJURY DUE TO LIFTING (OSHA REPORTABLE INJURIES), COMPANY #1

	1990			1991			1992*			Acceptability of Task	
	Work Hours	Number Injuries	Incidence Rate	Work Hours	Number Injuries	Incidence Rate	Work Hours	Number Injuries	Incidence Rate**	1981	1991
Job 1	472036	0	0.00	451333	0	0.00	296432	0	0.00		
Task 1										A	A
Task 2***										A	A
Task 3***										A	A
Job 2	291212	2	1.37	278440	4	2.87	182877	1	0.73		
Task 4										AWC	NA
Task 5										AWC	NA
Job 3	262210	2	1.53	250709	4	3.19	164664	2	1.62		
Task 6										A	NA
Task 7***										A	NA
Job 4	163067	3	3.68	155915	4	5.13	102404	0	0.00		
Task 8										AWC	NA
Task 9***										AWC	NA
Job 5	104765	21	40.09	100171	7	13.98	65791	0	0.00		
Task 10***										A	A
Task 11***										AWC	NA
Job 6 (Task 12)	34161	11	64.40	33677	3	17.82	22277	2	11.97	NA	NA
Job 7 (Task 13)	11380	1	17.57	11219	5	89.13	7420	0	0.00	AWC	NA
Job 8	18682	0	0.00	16613	3	36.12	10398	0	0.00		
Task 14										A	A
Task 15										A	NA

Legend: A = Acceptable
AWC = Acceptable with Controls
NA = Not Acceptable

* through August, 1992
**based on 133,333.3 hours
*** denotes asymmetrical lifts

TABLE 32

INCIDENCE OF INJURY DUE TO LIFTING (ALL INJURIES), COMPANY #3

	1990			1991			1992*			Acceptability of Task	
	Work Hours	Number Injuries	Incidence Rate	Work Hours	Number Injuries	Incidence Rate	Work Hours	Number Injuries	Incidence Rate**	1981	1991
Job 12	10500	0	0.00	10500	1	19.05	7000	1	19.05		
Task 21										A	A
Task 22***										A	A
Task 23										A	A
Task 24										A	A
Job 13	5250	0	0.00	5250	2	76.19	3500	0	0.00		
Task 25										AWC	NA
Task 26										AWC	NA
Task 27										AWC	NA
Task 28										AWC	NA
Job 14	10500	1	19.05	10500	0	0.00	7000	0	0.00		
Task 29***										A	NA
Task 30***										A	NA
Job 15	22500	1	8.89	22500	2	17.78	15000	8	71.11		
Task 31***										AWC	NA

* through August, 1992
**based on 133,333.3 hours
*** denotes asymmetrical lifts

Legend:
A = Acceptable
AWC = Acceptable with Controls
NA = Not Acceptable

TABLE 33

INCIDENCE OF INJURY FROM LIFTING (OSHA REPORTABLE INJURIES), COMPANY #3

	1990			1991			1992*			Acceptability of Task	
	Work Hours	Number Injuries	Incidence Rate	Work Hours	Number Injuries	Incidence Rate	Work Hours	Number Injuries	Incidence Rate**	1981	1991
Job 12	10500	0	0.00	10500	1	19.05	7000	1	19.05		
Task 21										A	A
Task 22***										A	A
Task 23										A	A
Task 24										A	A
Job 13	5250	0	0.00	5250	1	38.10	3500	0	0.00		
Task 25										AWC	NA
Task 26										AWC	NA
Task 27										AWC	NA
Task 28										AWC	NA
Job 14	10500	0	0.00	10500	0	0.00	7000	0	0.00		
Task 29***										A	NA
Task 30***										A	NA
Job 15	22500	0	0.00	22500	2	17.78	15000	4	35.56		
Task 31***										AWC	NA

* through August, 1992
**based on 133,333.3 hours
*** denotes asymmetrical lifts

Legend: A = Acceptable
AWC = Acceptable with Controls
NA = Not Acceptable

APPENDIX II

SAS PRINTOUTS

OBS	SEQ	CO	JOB	TASK	WL	CWL	HO	HD	VO	VD	D	HUSED	PO	PD	F	CFL	DUR	CDL	AO	AD	CPL	TPL	FD	HF81	VF81	DF81	FF81
1	1	1	1	1	8.0	2	25.4	38.1	121.9	172.7	50.8	38.1	1	1	0.05	1	7.5	3	0	0	2	6	40.0	0.39	0.81	0.85	1.00
2	2	1	1	2	6.8	2	30.5	50.8	139.7	139.7	0.0	50.8	1	1	0.20	1	7.5	3	0	30	1	1	40.6	0.30	0.74	1.00	0.99
3	3	1	1	3	4.7	1	43.2	43.2	35.6	43.2	7.6	43.	2	2	0.07	1	7.5	3	45	0	2	6	55.6	0.35	0.84	1.00	1.00
4	4	1	2	1	12.2	3	33.0	48.3	132.1	167.6	35.6	48.3	1	1	0.05	1	7.5	3	0	0	2	6	35.6	0.31	0.77	0.91	1.00
5	5	1	2	2	19.6	4	43.2	38.1	109.2	94.0	15.2	43.2	1	2	0.03	1	7.5	3	0	0	2	4	40.6	0.35	0.86	1.00	1.00
6	6	1	3	1	7.3	2	33.5	41.9	96.5	144.8	48.3	41.9	1	1	3.30	4	7.5	3	0	0	2	3	67.3	0.36	0.91	0.87	0.78
7	7	1	3	2	3.1	1	73.3	33.5	66.0	66.0	0.0	73.3	2	2	3.30	4	7.5	3	45	45	3	3	67.3	0.20	0.96	1.00	0.73
8	8	1	4	1	10.2	3	38.1	53.3	141.0	170.2	29.2	53.3	1	1	5.00	5	7.5	3	0	0	2	2	65.6	0.28	0.74	0.96	0.67
9	9	1	4	2	6.8	2	45.7	45.7	170.2	91.4	78.7	45.7	1	1	5.00	5	7.5	3	45	30	2	2	65.6	0.33	0.62	0.80	0.67
10	10	1	5	1	1.1	1	41.9	48.3	96.5	124.5	27.9	48.3	1	1	6.00	6	7.5	3	0	90	2	4	43.2	0.31	0.91	0.97	0.60
11	11	1	5	2	15.4	4	43.2	43.2	114.3	81.3	33.0	43.2	2	2	0.50	1	7.5	3	0	15	2	4	44.5	0.35	0.84	0.93	0.96
12	12	1	6	1	19.1	4	31.8	80.0	78.6	19.1	68.6	80.0	1	2	6.00	6	0.5	1	0	0	2	4	38.1	0.19	0.95	0.81	0.60
13	13	1	7	1	11.2	3	30.5	76.2	90.2	53.3	36.8	76.2	1	2	6.00	6	3.0	2	0	0	2	4	27.9	0.20	0.94	0.90	0.60
14	14	1	8	1	10.7	3	20.3	63.5	101.6	152.4	50.8	63.5	1	1	1.00	2	2.0	2	0	0	3	5	60.0	0.74	0.89	0.85	0.93
15	15	1	8	2	17.7	4	20.3	76.2	121.9	165.1	43.2	76.2	1	1	2.00	2	2.0	2	0	0	3	5	120.0	0.74	0.81	0.87	0.87
16	16	2	9	1	6.4	2	30.9	29.2	74.9	80.0	5.1	30.9	1	1	0.90	1	8.0	3	0	0	2	4	58.4	0.48	1.00	1.00	0.93

OBS	ACP81	ASY	HF91O	VF91O	DF91O	FF91O	AF91O	CF91O	HF91D	VF91D	DF91D	FF91D	AF91D	CF91D	ACP91	AL	ALN	MPL	MPLN
1	1	1	0.98	0.86	0.91	1.00	1.00	1.00	0.66	0.71	0.91	1.00	1.00	1.00	1	10.7406	1766.06	32.2218	5298.17
2	1	0	0.82	0.81	1.00	0.85	1.00	1.00	0.49	0.81	1.00	0.85	0.90	1.00	1	8.7912	2108.88	26.3736	6326.64
3	1	0	0.58	0.88	1.00	1.00	0.86	0.95	0.58	0.90	1.00	1.00	1.00	0.95	1	11.7600	1808.64	35.2800	5425.92
4	2	1	0.76	0.83	0.95	1.00	1.00	1.00	0.52	0.72	0.95	1.00	1.00	1.00	3	8.6887	2142.14	26.0660	6426.42
5	2	1	0.58	0.90	1.00	1.00	1.00	1.00	0.66	0.94	1.00	1.00	1.00	1.00	3	12.0400	1808.85	36.1200	5426.54
6	1	1	0.75	0.94	0.91	0.45	1.00	1.00	0.60	0.79	0.91	0.45	1.00	1.00	3	8.8924	1890.53	26.6771	5671.58
7	1	0	0.34	0.97	1.00	0.45	0.86	0.90	0.75	0.97	1.00	0.45	0.86	0.90	3	5.6064	3167.28	16.8192	9501.84
8	2	1	0.66	0.80	0.97	0.35	1.00	1.00	0.47	0.71	0.97	0.35	1.00	1.00	3	5.3308	2306.59	15.9925	6919.76
9	2	0	0.55	0.71	0..8	0.35	0.86	1.00	0.55	0.95	0.88	0.35	0.90	1.00	3	4.3866	2155.34	13.1599	6466.01
10	1	0	0.60	0.94	0.98	0.27	1.00	1.00	0.52	0.85	0.98	0.27	0.71	1.00	1	6.5673	2074.42	19.7019	6223.25
11	2	0	0.58	0.88	0.96	0.81	1.00	1.00	0.58	0.98	0.96	0.81	0.95	1.00	3	10.4993	1876.71	31.4980	5630.12
12	3	1	0.79	0.96	0.89	0.75	1.00	1.00	0.31	0.83	0.89	0.75	1.00	0.95	3	3.5089	3724.79	10.5268	11174.37
13	2	1	0.82	0.95	0.94	0.50	1.00	1.00	0.33	0.93	0.94	0.50	1.00	0.95	3	4.0608	3342.86	12.1824	10028.58
14	1	1	1.00	0.92	0.91	0.88	1.00	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1	20.8249	931.18	62.4748	2793.55
15	1	1	1.00	0.86	0.92	0.84	1.00	0.90	1.00	1.00	1.00	1.00	1.00	1.00	3	18.1474	919.19	54.4423	2757.58
16	1	1	0.81	0.87	1.00	0.75	1.00	0.95	0.86	0.85	1.00	0.75	1.00	1.00	1	17.8560	1320.00	53.5680	3960.00

OBS	RWLO	RWLON	RWLD	RWLDN	RWL	RWLN	LI91	LI81	DIFLI	DIFAW	PDIFAW	DWLAL	DWLRWL	ABDWLAL	ABDWLRWL
1	17.6398	23	9.8078	23	9.8078	23	0.81568	0.74484	0.07084	0.93280	8.6848	-2.7406	-1.8078	2.7406	1.8078
2	12.9851	23	6.9835	23	6.9835	23	0.97373	0.77350	0.20023	1.80774	20.5631	-1.9912	-0.1835	1.9912	0.1835
3	9.5909	23	11.4057	23	9.5909	23	0.49005	0.39966	0.09039	2.16907	18.4445	-7.0600	-4.8909	7.0600	4.8909
4	13.7830	23	8.1806	23	8.1806	23	1.49133	1.40413	0.08720	0.50804	5.8471	3.5113	4.0194	3.5113	4.0194
5	12.0060	23	14.2692	23	12.0060	23	1.63252	1.62791	0.00461	0.03400	0.2824	7.5600	7.5940	7.5600	7.5940
6	6.6400	23	4.4644	23	4.4644	23	1.63517	0.82093	0.81424	4.42801	49.7955	-1.5924	2.8356	1.5924	2.8356
7	2.6420	23	5.8279	23	2.6420	23	1.17336	0.55294	0.62042	2.96441	52.8754	-2.5064	0.4580	2.5064	0.4580
8	4.1229	23	2.6057	23	2.6057	23	3.91450	1.91339	2.00111	2.72515	51.1204	4.8692	7.5943	4.8692	7.5943
9	2.3790	23	3.3313	23	2.3790	23	2.85832	1.55017	1.30815	2.00760	45.7665	2.4134	4.4210	2.4134	4.4210
10	3.4324	23	1.9098	23	1.9098	23	0.57596	0.16750	0.40847	4.65744	70.9188	-5.4673	-0.8098	5.4673	0.8098
11	9.1284	23	9.6574	23	9.1284	23	1.68704	1.46676	0.22028	1.37093	13.0573	4.9007	6.2716	4.9007	6.2716
12	11.6433	23	3.7527	23	3.7527	23	5:08968	5.44327	-0.35359	-0.24377	-6.9471	15.5911	15.3473	15.5911	15.3473
13	8.4210	23	3.1517	23	3.1517	23	3.55363	2.75808	0.79555	0.90909	22.3870	7.1392	8.0483	7.1392	8.0483
14	15.2504	23	23.0000	23	15.2504	23	0.70162	0.51381	0.18781	5.57450	26.7684	-10.1249	-4.5504	10.1249	4.5504
15	13.7574	23	23.0000	23	13.7574	23	1.28658	0.97534	0.31124	4.39005	24.1910	-0.4474	3.9426	0.4474	3.9426
16	11.5483	23	12.6097	23	11.5483	23	0.55420	0.35842	0.19577	6.30773	35.3255	-11.4560	-5.1483	11.4560	5.1483

OBS	SEQ	CO	JOB	TASK	WL	CWL	HO	HD	VO	VD	D	HUSED	PO	PD	F	CFL	DUR	CDL	AO	AD	CPL	TPL	FD	HF81	VF81	DF81	FF81
17	17	2	10	1	15.4	4	30.9	54.4	78.7	94.6	15.9	54.4	1	1	1.00	2	8.0	3	0	0	2	4	31.8	0.28	0.99	0.93	1.00
18	18	2	10	2	6.4	2	30.9	53.3	78.7	25.4	53.3	53.3	1	2	1.00	2	8.0	3	0	0	2	4	31.8	0.28	0.99	0.84	0.53
19	19	2	11	1	9.1	2	42.9	63.5	87.6	24.1	63.5	63.5	1	2	0.50	1	8.0	3	0	0	2	4	55.9	0.24	0.95	0.96	0.82
20	20	2	11	2	8.2	2	16.0	40.4	88.9	110.5	21.6	40.4	1	1	0.50	1	8.0	3	0	0	3	5	53.3	0.37	0.94	0.96	1.00
21	21	3	12	1	2.9	1	30.2	40.4	116.8	139.7	22.9	40.4	1	1	0.01	1	0.5	1	0	0	2	5	14.6	0.50	0.83	1.00	1.00
22	22	3	12	2	2.4	1	63.5	79.1	76.2	114.3	38.1	79.1	1	1	0.05	1	0.5	1	15	0	3	5	125.0	0.19	1.00	0.90	0.99
23	23	3	12	3	2.0	1	53.1	76.2	137.2	63.5	73.3	76.2	1	2	0.20	1	8.0	3	0	0	3	5	90.0	0.20	0.75	0.80	0.97
24	24	3	12	4	17.6	4	27.1	44.5	74.2	127.0	52.8	44.5	2	1	0.01	1	0.1	1	0	0	2	6	50.2	0.38	1.00	0.97	0.84
25	25	3	13	1	8.5	2	30.2	53.1	175.0	91.4	86.4	53.1	1	1	0.40	1	8.0	3	0	0	2	5	10.2	0.50	0.59	0.79	0.97
26	26	3	13	2	5.3	2	30.2	35.3	56.5	91.4	34.9	35.3	2	1	0.40	1	8.0	3	0	0	2	5	12.2	0.50	0.93	0.92	0.97
27	27	3	13	3	2.0	1	30.2	35.3	111.8	91.4	20.4	35.3	1	1	0.40	1	8.0	3	0	0	2	5	12.6	0.50	0.85	1.00	0.97
28	28	3	13	4	25.4	6	50.6	50.6	91.4	147.3	55.9	50.6	1	1	0.20	1	8.0	3	0	0	2	5	90.0	0.30	0.93	0.83	0.99
29	29	3	14	1	11.4	3	40.6	20.1	87.6	106.1	18.5	40.6	1	1	1.00	2	0.5	1	10	0	3	7	30.5	0.37	0.95	1.00	0.94
30	30	3	14	2	22.7	5	35.7	35.3	57.2	73.7	16.5	35.7	2	1	1.00	2	0.5	1	15	0	3	5	54.2	0.42	0.93	1.00	0.93
31	31	3	15	1	3.5	1	43.2	71.1	7.6	142.2	134.6	71.1	2	1	3.30	4	8.0	3	30	45	2	5	22.9	0.35	0.73	0.78	0.76

OBS	ACP81	ASY	HF910	VF910	DF910	FF910	AF910	CF910	HF91D	VF91D	DF91D	FF91D	AF91D	CF91D	ACP91	AL	ALN	MPL	MPLN
17	2	1	0.81	0.85	1.00	0.75	1.00	1.00	0.46	0.81	1.00	0.75	1.00	1.00	3	10.3118	2347.89	30.9355	7043.66
18	2	1	0.81	0.85	0.91	0.75	1.00	1.00	0.47	0.99	0.91	0.75	1.00	0.95	1	4.9364	2478.23	14.8091	7434.68
19	2	1	0.58	0.83	0.89	0.81	1.00	1.00	0.39	0.98	0.89	0.81	1.00	0.95	3	7.1793	2694.23	21.5378	8082.70
20	1	1	1.00	0.82	1.00	0.81	1.00	0.90	0.62	0.76	1.00	0.81	1.00	0.90	3	13.3555	1747.51	40.0666	5242.54
21	1	1	0.83	0.74	1.00	1.00	1.00	1.00	0.62	0.67	1.00	1.00	1.00	1.00	1	16.6000	1265.98	49.8000	3797.93
22	1	0	0.39	0.86	0.94	1.00	0.95	0.90	0.32	0.75	0.94	1.00	1.00	0.90	1	6.7716	3520.00	20.3148	10560.00
23	1	1	0.47	0.68	0.88	0.85	1.00	0.90	0.33	0.90	0.88	0.85	1.00	0.90	1	4.6560	3558.94	13.9680	10676.81
24	2	1	0.92	0.87	0.91	1.00	1.00	0.95	0.56	0.71	0.91	1.00	1.00	1.00	3	12.3850	1693.15	37.1549	5079.46
25	1	1	0.83	0.56	0.87	0.81	1.00	1.00	0.47	0.82	0.87	0.81	1.00	1.00	3	9.0423	1432.28	27.1270	4296.84
26	1	1	0.83	0.92	0.95	0.81	1.00	0.95	0.71	0.82	0.95	0.81	1.00	1.00	1	16.5986	1321.77	49.7959	3965.31
27	1	1	0.83	0.76	1.00	0.81	1.00	1.00	0.71	0.82	1.00	0.81	1.00	1.00	1	16.4900	1266.12	49.4700	3798.36
28	2	1	0.94	0.82	0.90	0.85	1.00	1.00	0.49	0.65	0.90	0.85	1.00	1.00	3	9.1702	2327.36	27.5105	6982.09
29	1	0	0.62	0.83	1.00	0.94	0.97	0.90	1.00	1.00	1.00	1.00	1.00	1.00	3	13.2164	1711.95	39.6492	5135.84
30	2	0	0.70	0.92	1.00	0.94	0.95	0.90	1.00	1.00	1.00	1.00	1.00	1.00	3	14.5303	1507.97	43.5910	4523.91
31	1	0	0.58	0.93	0.85	0.55	0.90	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1	6.0584	2062.41	18.1752	6187.24

OBS	RWLO	RWLON	RWLD	RWLDN	RWL	RWLN	LI91	LI81	DIFLI	DIFAW	PDIFAW	DWLAL	DWLRWL	ABDWLAL	ABDWLRWL
17	11.8766	23	6.4274	23	6.4274	23	2.39601	1.49343	0.90258	3.88449	37.6702	5.0882	8.9727	5.0882	8.9727
18	10.8077	23	6.9388	23	6.9388	23	0.92234	1.29650	-0.37415	-2.00247	-40.5655	1.4636	-0.5388	1.4636	0.5388
19	7.9819	23	6.0203	23	6.0203	23	1.51156	1.26754	0.24402	1.15898	16.1434	1.9207	3.0797	1.9207	3.0797
20	13.7489	23	7.9006	23	7.9006	23	1.03789	0.61398	0.42392	5.45491	40.8439	-5.1555	0.2994	5.1555	0.2994
21	14.1266	23	9.5542	23	9.5542	23	0.30353	0.17470	0.12883	7.04580	12.4446	-13.7000	-6.6542	13.7000	6.6542
22	6.1999	23	4.6699	23	4.6699	23	0.51393	0.35442	0.15951	2.10168	31.0367	-4.3716	-2.2699	4.3716	2.2699
23	4.9486	23	4.5986	23	4.5986	23	0.43491	0.42955	0.00536	0.05737	1.2322	-2.6560	-2.5986	2.6560	2.5986
24	15.9148	23	8.3218	23	8.3218	23	2.11494	1.42108	0.69386	4.06319	32.8075	5.2150	9.2782	5.2150	9.2782
25	7.5335	23	6.2466	23	6.2466	23	1.36074	0.94002	0.42072	2.79574	30.9183	-0.5423	2.2534	0.5423	2.2534
26	12.8388	23	10.3041	23	10.3041	23	0.51436	0.31930	0.19506	6.29457	37.9222	-11.2986	-5.0041	11.2986	5.0041
27	11.7518	23	10.8464	23	10.8464	23	0.18439	0.12129	0.06311	5.64361	34.2245	-14.4900	-8.8464	14.4900	8.8464
28	13.5622	23	5.6040	23	5.6040	23	4.53247	2.76985	1.76262	3.56616	38.8887	16.2298	19.7960	16.2298	19.7960
29	9.7127	23	23.0000	23	9.7127	23	1.17372	0.86256	0.31116	3.50371	26.5103	-1.8164	1.6873	1.8164	1.6873
30	11.9044	23	23.0000	23	11.9044	23	1.90686	1.56225	0.34461	2.62592	18.0720	8.1697	10.7956	8.1697	10.7956
31	4.9589	23	23.0000	23	4.9589	23	0.70330	0.57771	0.12809	1.09950	18.1484	-2.5584	-1.4589	2.5584	1.4589

APPENDIX III

ERGONOMIC TASK ANALYSIS DECISIONS

The evaluation of a lifting task requires certain decision to be made based on the conduct of the tasks. The decisions involved with each task evaluation are outlined below. Only those lifts which required decisions are listed.

1. N=1. 1981 Equation: Horizontal Distance Used: Destination

Rationale: The worker was required to place the load, a roll of paper, on a spindle, aligning the load at the destination. This required a great amount of control of the load while it was held above the worker's head. Using the destination horizontal factor resulted in a HF of .39, with an AL of 10.7 kg. Had the horizontal factor at the origin been used, the HF would have been .59, and the resultant AL would equal 16.2 kg. Since the weight of the load lifted was 8.0 kg, this lift would be rated acceptable either way.

2. N=2 This lift is an asymmetrical lift, which technically cannot be evaluated using the 1981 lifting equation.

1981 Equation: Horizontal Distance Used: Destination

Rationale: The worker was required to remove the load, a rectangular box, from an overhead holder, and align the load in another overhead holder. This required control of the load while it was held above the worker's head. Using the destination horizontal factor resulted in a HF of .30, with an AL of 8.8 kg. Had the horizontal factor at the origin been used, the HF would have been .49, and the resultant AL would equal 14.4 kg. Since the weight of the load lifted was 8.8 kg, this lift would be rated acceptable either way.

3. N=4. 1981 Equation: Horizontal Distance Used: Destination

Rationale: The worker was required to place the load on a spindle, aligning the load at the destination. This required a great amount of control of the load while it was held above the worker's head. Using the destination horizontal factor resulted in a HF of .31, with an AL of 8.7 kg. Had the horizontal factor at the origin been used, the HF would have been .45, and the resultant AL would equal 12.6 kg. Since the weight of the load lifted was 12.2 kg, this lift would be rated acceptable with controls (AWC) using the destination horizontal factor and acceptable using the origin horizontal factor.

4. N=6 1981 Equation: Horizontal Distance Used: Destination

Rationale: The worker was required to lift the load, a rectangular box, and place the load in a rack, aligning it in a slot designed to fit the load. This required control of the load while it was held away from the worker's body. Using the destination horizontal factor resulted in a HF of .36, with an AL of 8.9 kg. Had the horizontal factor at the origin been used, the HF would have been .45, and the resultant AL would equal 11.1 kg. Since the weight of the load lifted was 7.3 kg, this lift would be rated acceptable either way.

5. N=8. 1981 Equation: Horizontal Distance Used: Destination

Rationale: The worker was required to remove the load, a rectangular box, from a rack, and align the load in an overhead holder. This required control of the load while it was held above the worker's head. Using the destination horizontal factor resulted in a HF of .28, with an AL of 5.3 kg. Had the horizontal factor at the origin been used, the HF would have been .39, and the resultant AL would equal 7.4 kg. Since the weight of the load lifted was 10.2 kg, this lift would be rated acceptable with controls (AWC) either way.

6. N=10. This lift is an asymmetrical lift, which technically cannot be evaluated using the

1981 lifting equation.

1981 Equation: Horizontal Distance Used: Destination

Rationale: In this lift, the worker was loading a box with items fed to him on a conveyor. This required control of the load as it was being placed in to the box. Using the destination horizontal factor resulted in a HF of .31, with an AL of 6.6 kg. Had the horizontal factor at the origin been used, the HF would have been .36, and the resultant AL would equal 7.6 kg. Since the weight of the load lifted was 1.1 kg, this lift would be rated acceptable either way.

7. N=12. This lift is an asymmetrical lift, which technically cannot be evaluated using the 1981 lifting equation.

1981 Equation: Horizontal Distance Used: Destination

Rationale: In this lift, the worker was stacking boxes onto a pallet. Upon lowering the load to the pallet, the load was held with some degree of control quite a distance from the body. This work was quite strenuous to the worker, who appeared to be in relatively good condition. Using the destination horizontal factor resulted in a HF of .19, with an AL of 3.5 kg. Had the horizontal factor at the origin been used, the HF would have been .47, and the resultant AL would equal 8.7 kg. Since the weight of the load lifted was 19.1 kg, this lift was rated unacceptable using the destination horizontal factor, but would have been AWC had the origin horizontal factor been used.

8. N=13. 1981 Equation: Horizontal Distance Used: Destination

Rationale: In this lift, the worker was palletizing boxes from a conveyor. The boxes had to be lowered with some degree of control as they we placed at the destination. Using the destination horizontal factor resulted in a HF of .20, with an AL of 4.1 kg. Had the horizontal factor at the origin been used, the HF would have been .49, and the resultant AL would equal 9.9 kg. Since the weight of the load lifted was 11.2 kg, this lift would be rated acceptable with controls (AWC) either way.

1981 and 1991 Equation: Duration category

9. N=17. 1981 Equation: Horizontal Distance Used: Destination

Rationale: In this lift, the worker was palletizing boxes from a conveyor. The boxes had to be lowered with some degree of control as they we placed at the destination. Using the destination horizontal factor resulted in a HF of .28, with an AL of 10.3 kg. Had the horizontal factor at the origin been used, the HF would have been .48, and the resultant AL would equal 17.67 kg. Since the weight of the load lifted was 15.4 kg, this lift would be rated acceptable rather than AWC, had the origin distance been used.

10. N=18. 1981 Equation Horizontal Distance Used: Destination

Rationale: This lift was similar to N = 17, with the worker controlling the box as it was put in place. Using the destination horizontal factor resulted in a HF of .28, with an AL of 4.9 kg. Had the horizontal factor at the origin been used, the HF would have been .48, and the resultant AL would equal 8.5 kg. Since the weight of the load lifted was 6.4 kg, this lift would be rated acceptable rather than AWC, had the origin distance been used.

11. N=19. 1981 Equation: Horizontal Distance Used: Destination

Rationale: In this lift, the worker lifted a rather large box from a work table onto a stack of boxes. The box contained a part and required control throughout the lift. Using the destination horizontal factor resulted in a HF of .24, with an AL of 7.2 kg. Had the horizontal factor at the origin been used, the HF would have been .35, and the resultant AL would equal 10.4 kg. Since the weight of the load lifted was 9.1 kg, this lift would be rated acceptable rather than AWC, had the origin distance been used.

12. N=20. 1981 Equation: Horizontal Distance Used: Destination

Rationale: In this lift, the worker was required to lift the load and orient it on a work table. This required a control of the load while it was being placed at the destination. Using the destination horizontal factor resulted in a HF of .37, with an AL of 13.4 kg. Had the horizontal factor at the origin been used, the HF would have been .94, and the resultant AL would equal 33.93 kg. Since the weight of the load lifted was 8.2 kg, this lift would be rated acceptable in either case.

13. N=22. 1981 Equation: Horizontal Distance Used: Destination

Rationale: The worker placed a large piece of packing material on top of a pile of material. This lift required more control at the destination than at the origin. Using the destination horizontal factor resulted in a HF of .19, with an AL of 6.8 kg. Had the horizontal factor at the origin been used, the HF would have been .24, and the resultant AL would equal 8.5 kg. Since the weight of the load lifted was 2.4 kg, this lift would be rated acceptable either way.

14. N=23. 1981 Equation: Horizontal Distance Used: Destination

Rationale: The worker placed a large piece of packing material on top of a product. This lift required more control at the destination than at the origin. Using the destination horizontal factor resulted in a HF of .20, with an AL of 4.7 kg. Had the horizontal factor at the origin been used, the HF would have been .28, and the resultant AL would equal 6.5 kg. Since the weight of the load lifted was 2.0 kg, this lift would be rated acceptable either way.

15. N=24. 1981 Equation: Horizontal Distance Used: Destination

Rationale: In this lift. the worker had to lower the load onto a vertical spindle, requiring considerable control at the destination. Using the destination horizontal factor resulted in a HF of .38, with an AL of 12.4 kg. Had the horizontal factor at the origin been used, the HF would have been .55, and the resultant AL would equal 17.9 kg. Since the weight of the load lifted was 17.6 kg, the rating of this lift would change from acceptable with controls to acceptable is the origin horizontal distance was used.

APPENDIX IV

FREQUENCY AND COUPLING FACTOR TABLES, 1991 GUIDE

1. In the 1991 Guide, the frequency factor and coupling factor for a lifting task are computed through the use of tables, rather than through the use of mathematical computation. Table 34 is used to extrapolate the frequency factor. Tables 35 and 36 are used to determine the coupling factor.

2. Frequency factor.

In measuring a lifting task, the analyst records the frequency of lifting in lifts per minutes, the duration of the lifting task, and the vertical height of the hands. This data is used to extrapolate the frequency factor from Table 34. Duration of the working task is categorized as ≤1 hour, ≤2 hours, or ≤8 hours. The vertical height, measured in centimeters categorized as <75 centimeters or ≥75 centimeters. Table 34 is entered at the top with the duration value. A column is selected to correspond the vertical height. Lifts per minute is read across from the left side of the table. The value extrapolated from the table is used directly as the frequency factor in the 1991 lifting equation. Lifts with a frequency of less than 0.2 lifts per minute are assigned a frequency factor of 1.00.

3. Coupling factor.

The first step in figuring the coupling factor is to determine from Table 35 if the hand-to-container coupling meets the criteria defined in the table as a Good, Fair, or Poor coupling. A good coupling occurs when the container is of optimal design as defined in Table 35. A fair coupling results from less than optimal container design. Poor couplings include containers that are bulky or hard to handle (Knill, 1992). Once the nature of the coupling has been categorized a Good, Fair, or Poor has been determined, Table 36 is entered with that category and the vertical height. The numbers extrapolated from the table are used directly as the coupling factor in the 1991 lifting equation.

TABLE 34

FREQUENCY FACTOR FOR 1991 GUIDE
(after Putz-Anderson and Waters, 1991)

Frequency Lifts/Min	Work Duration ≤1 hour V<75	≤1 hour V≥75	≤ 2 hours V<75	≤ 2 hours V≥75	≤ 8 hours V<75	≤ 8 hours V≥75
0.2	1.00	1.00	0.95	0.95	0.85	0.85
0.5	0.97	0.97	0.92	0.92	0.81	0.81
1	0.94	0.94	0.88	0.88	0.75	0.75
2	0.91	0.91	0.84	0.84	0.65	0.65
3	0.88	0.88	0.79	0.79	0.55	0.55
4	0.84	0.84	0.72	0.72	0.45	0.45
5	0.80	0.80	0.60	0.60	0.35	0.35
6	0.75	0.75	0.50	0.50	0.27	0.27
7	0.70	0.70	0.42	0.42	0.22	0.22
8	0.60	0.60	0.35	0.35	0.18	0.18
9	0.52	0.51	0.30	0.30	0.00	0.15
10	0.45	0.45	0.26	0.26	0.00	0.13
11	0.41	0.41	0.00	0.23	0.00	0.00
12	0.37	0.37	0.00	0.21	0.00	0.00
13	0.00	0.34	0.00	0.00	0.00	0.00
14	0.00	0.31	0.00	0.00	0.00	0.00
15	0.00	0.28	0.00	0.00	0.00	0.00
>15	0.00	0.00	0.00	0.00	0.00	0.00

Values of V are in cm.

TABLE 35

CLASSIFICATION OF COUPLING, 1991 GUIDE
(after Putz-Anderson and Waters, 1991)

GOOD	FAIR	POOR
1. For containers of optimal design, such as some boxes, crates, etc., a "Good" hand-to-object coupling would be defined as handles or hand-hold cut-outs of optimal design (see notes 1 to 3 below).	1. For containers of optimal design, such as some boxes, crates, etc., a "Fair" hand-to-object coupling would be defined as handles or hand-hold cut-outs of less than optimal design (see notes 1 to 3 below).	1. Containers of less than optimal design with no handles of hand-hold cutouts or loose parts or irregular objects that are bulky or hard to handle (see note 5 below).
2. For loose parts or irregular objects, which are not usually containerized, such as castings, stock, supply materials, etc., a "Good" hand-to-object coupling would be defined as a comfortable grip in which the hand can be easily wrapped around the object (see note 6 below).	For containers of optimal design with no handles or hand-hold cut-outs or for loose parts or irregular objects, a "Fair" hand-to-object coupling is defined as a grip in which the hand can be flexed about 90 degrees (see note 4 below).	

1. An optimal handle design has 1.9 to 3.8 cm (0.75 to 1.5 in) diameter, ≥ 11.5 cm (4.5 in) length, 5 cm (2 in) clearance, cylindrical shape, and a smooth, non-slip surface.

2. An optimal hand-hold cut-out has ≥ 3.8 cm (3 in) height, 11.5 cm (4.5 in) length, semi-oval shape, ≥ 5 cm (2 in) clearance, smooth non-slip surface, and ≥ 1.1 cm (0.43 in) container thickness.

3. An optimal container design has ≤ 40 cm (16 in) frontal length, ≤ 30 cm (12 in) height, and a smooth non-slip surface.

4. A worker should be capable of clamping the fingers at nearly 90 degrees under the container, such as required when lifting a cardboard box from the floor.

5. A less-than-optimal container has a frontal length ≥ 40 cm (16 in), height ≥ 30 cm (12 in), rough or slippery surface, sharp edges, asymmetric center of mass, unstable contents, or require gloves.

TABLE 32 (continued)

6. A worker should be able to comfortably wrap the hand around the object without causing excessive wrist deviations or awkward postures and the grip should not require excessive force.

The following decision tree is provided to assist the analyst in classifying the hand-to-object coupling.

If the object lifted is a container (e.g., box, crate, or container, etc.), go to Section 1. If the object is a loose part or irregular object (e.g., castings, stock supply materials, etc.), then go to Section 2.

Section 1: If the container is of optimal design, go to 1a. Otherwise, go to 1b.

1a: If the container has optimal handles or hand-t-c cut-outs, then go to 1a1. Otherwise go to 1a2.

1a1: The coupling is classified as "Good."

1a2: If the fingers can be clamped or flexed about 90 degrees under the container, then the coupling is classified as "Fair." Otherwise the coupling is classified as "Poor."

Section 2: If the hand can be easily wrapped around the object in a comfortable grip, then go to 2a. Otherwise go to 2b.

2a: The coupling is classified as "Good."

2b: If the fingers can be flexed by about 90 degrees, then go to 2b1. Otherwise, go to 2b2.

2b1: The coupling is classified as "Fair."

2b2: The coupling is classified as "Poor."

Coupling Multiplier:

The Coupling Multiplier is determined from Table 36.

TABLE 36

DETERMINATION OF COUPLING FACTOR
(after Putz-Anderson and Waters, 1991)

COUPLING	V < 75cm	V ≥ 75 cm
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

APPENDIX V

DESCRIPTION OF JOBS

1. Company #1 (eight jobs):

Jobs #1 involved the operator of an automatic production machine. The worker was required to monitor the machine and restock the machine on a regular basis. Three lifts were observed at this work station (N=1,2,3).

Jobs #2 involved the operators of an automatic packaging machine. The worker was required to monitor the machine and restock the machine on a regular basis. Two lifts were observed at this work station (N=4,5).

Jobs #3 involved a worker who removed trays of finished product and replaced empty trays at a number of production workstations. Two lifts were observed for this job (N=6,7).

Job #4 involved a worker who brought stock to a number of production workstations. This workers exchanged full and empty containers as appropriate at each workstation. Two lifts were observed for this job (N=8,9).

Job #5 was a handpacking operation which is partially automated within the plant. Handpacking of cases is conducted occasionally when automated machines are down, and full time for those production lines in which casing is not yet automated. Two lifts were observed (N=10,11). In the first lift, the worker lifts a product from a conveyor and places it in a box located on a stand which orients the box at an angle. The height of the stand is adjustable by the worker. When the box is full, the worker lifts the box from the stand and placed it on a conveyor.

Job #6 is representative of lifts conducted in the warehouse from which the production lines are supplied. Complete pallets are usually moved to the production lines. However, when less than a full pallet is required, workers depalletize the required quantity onto another pallet for movement to the production lines. (This usually involves those lifts of a palletizing operation which are least acceptable, going from any height on the original pallet to the lowest row of the new pallet.) One lift was analyzed for this job (N=12).

Job #7 involved taking cases from a conveyor and palletizing them. This job is partially automated, but is done by hand when production quantities exceed automation capabilities or automated equipment experiences down time. One lift was analyzed (N=13).

Job #8 involved uncrating raw materials. Workers remove the packing material from large crates of raw material which moves through the workstation on a conveyor. This job is performed as the need for raw materials occurs, usually daily only for a few hours at a time. Two lifts were analyzed (N=14,15)

2. Company #2 (three jobs):

Job #9 involved packaging a part in a cardboard box, then lifting that box from a conveyor and stacking the box on a pallet located on a pallet lifter (N=16). The worksite is set up so no lifting was involved in the packaging of the part. The worker adjusted the pallet lifter as layers of boxes were added to the pallet, keeping the destination at a constant height.

Job #10 involved taking cardboard boxes of various packaged assemblies from a conveyor and sorting them onto pallets located on the floor. Lifts of two different size loads were observed (N=17,18).

Job #11 involved a worker who packaged a part. Two lifts for the job (N=19,20) involved lifting a part to a table, packaging the part, then stacking the packaged parts on a pallet located on a hand truck.

3. Company #3.

Job #12 involved packaging a variety of product for shipping. Packaging requirements varied by product and location, but involved applying cardboard, wood and other packing materials to the product. Daily restock of a shrinkwrap machine was included in this job. Four lifts were observed at this job (N=21, 22, 23, 24).

Job #13 involved building pallets (skidmaking). Various sized boards were lifted to a table and assembled. The finished pallet was then loaded onto a forklift. The height of the forklift was adjusted by the skidmaker as the stack of finished pallets grew taller. Five lifts were recorded for this job. Four lifts involving lifting of component boards and one lift involved lifting the finished pallet to the forklift (N=25, 26, 27, 28). (The worker had the option of using the forklift to remove the finished pallet from the table.)

Job #14 involved stocking a furnace. The two observed lifts occurred when metal bar stock and bags were lifted from pallets and dumped into a furnace (N=29, 30).

Job #15 involved workers who removed and replaced brick from walls. After the bricks were knocked from the walls, the workers lifted the bricks from the floor and dumped them into a dumpster. TRebricking is usually done with one of three sizes of brick. The observed lift was for the smallest of the three size bricks (N=31). Working conditions for this job were hot and noisy.

VITA

Nina Lynn Brokaw graduated from Michigan State University in 1979. Upon graduation, she was commissioned a Second Lieutenant in the United States Army. She currently a holds the rank of Major. Major Brokaw has served at Aberdeen Proving Grounds, Maryland; Fort Carson, Colorado; Fort McClellan, Alabama; Fort Lewis, Washington; and Fort Knox, Kentucky. Her military education includes the Chemical Officer Basic Course, the Chemical Officer Advance Course, and the Material Acquisition Management Course. Among her awards and decorations are the Parachutist's Badge, the Meritorious Service Medal with oak leaf cluster, and the Army Commendation Medal with two oak leaf clusters. Upon completion of her studies she will attend the Command and General Staff College at Fort Leavenworth, Kansas. Major Brokaw is married to Major Jeffery Hill. They have one son, Jonathan Tyler Hill, born during her tour at the University of Louisville, and two dogs, a basset hound, Marlowe, and a chocolate lab, Max.